The rediscovery of time through its disappearance

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"*The history of natural philosophy is characterized by the interplay of two rivals philosophies of time – one aiming at its "elimination" and the other based on the belief that it is fundamental and irreducible*"(G.J. Whitrow, 1980).

Introduction ----------

Is time rooted in the very nature of reality or a mere but stubborn illusion ? Is time an inherent property of the world or a mind-dependent feature ? Time is at the crossroad of many disciplines : physics, philosophy and psychology. These multi-faceted aspects of the concept of time are intertwined, therefore it is quite difficult to contrast one with the others and conclude, like Einstein, at the time of his encounter with Bergson, that time for a philosopher differs from time for a physicist. Besides, Poincaré had noticed that issues and problems about the universe's time spring up from our intimate awareness of time and not the opposite[1]. The nature of time is a decisive question for Philosophy as it is for Physics. Faced with such a situation, Reichenbach considered that the philosophical problem of time had its solution in physics[2], whereas Cleugh judged that physics was much more concerned with the measure of time rather than with the question of its nature[3]. This quite common alternative does not seem to hold anymore today especially with the search of a quantum theory of gravity.

For loop theorists, General Relativity (GR) is not another field theory. With the concept of background independence, it has changed our understanding of space and time. Space and time can not anymore be considered as the passive containers of localisation and becoming.

[1] Cf. Poincaré (1905).
[2] "There is no other way to solve the problem of time than the way through physics. More than any other science, physics has been concerned with the nature of time" (Reichenbach, 1956, p.16).
[3] "It cannot be often too emphasized that physics is concerned with the measurement of time, rather than with the essentially metaphysical question as to its nature. […]. We must not believe that physical theories can ultimately solve the metaphysical problems that time raises" (Cleugh, 1937, p.51). We must not forget that the birth of modern physics with Galileo became possible by giving up the question of the nature of time and turning to the problem of its measure.

From this perspective, Loop Quantum Gravity is an attempt to construct and understand from a physical point of view a background independent theory of quantum gravity. What are the foundational significance and epistemological impact of background independence ? We uphold that it has changed and clarified the long-standing debate between time and becoming, but also that it gives an *a posteriori* answer to Bergson's criticism of time in physics. Time has often appeared as something less concrete and more immaterial than becoming. In this perspective, time has been understood as the structure of becoming or the concept whose content is change. By distinguishing the time-parameter from the time-dimension, GR and *a fortiori* quantum gravity, modify and reconfigure this traditional relation between time and becoming.

1. Essential temporality and timelessness in Physics

Time as immediately perceived or naively experienced involves three characteristics[4] : 1) a categorical distinction between past, present and future, 2) constant becoming and 3) a one-way irreversible direction. The past is fully determined, the present is inherently becoming and the future is undetermined. In view of these properties, closed past, creative present and open future, time in classical physics, mainly in Newtonian physics and in classical electrodynamics, appears totally irrelevant to time as we experience it. Indeed, it is well known that, with the exception of the second principle of thermodynamics, the equations of classical physics do not give evidence to time's irreversibility, quite the opposite[5]. This gap between physical time and experienced time has led to very distinct positions. For some thinkers, the timelessness of classical physics should make us realise that experienced time is an illusion as for others it shows physics' incompleteness in taking into account the world's essential temporality. In this dilemma, one will recognize nothing else than another expression of the antic controversy between Heraclitus and Parmenides.

2. Time and Becoming in Philosophy

Becoming refers to the universe's essential feature of fluidity and mobility. Becoming seems to constitute the nature of every being. Inert things as living beings are in a constant state of becoming. Everything undergoes changes and is transformed. The hardest stone as the most delicate flower, each in its own rhythm, change and eventually fade away. However, if everything flows, it is according to various modes, strongly heterogeneous one to another. Indeed, the birth of a being is not the same as the change of colour or the burst of a revolution in history. Becoming is the generic term whose different species are change, evolution, transformation, creation, destruction, decomposition, etc. The mobility specific of becoming is characterized by the uninterrupted sequence of changes[6]. Nevertheless, becoming is not only the sum of the various changes, it is more profoundly the blending, the extension and the scheduling of the various transformations. Thus, every change is never its own beginning or its own ending, it is more fundamentally the continuation of a transformation that preceded it.

It is common to say that things become *in* time but also that time flows. Is time the scene of what changes or the essence of becoming ? Do we have to identify time and becoming or differentiate them to see in time the container of changes ? Philosophical thought gave very distinct answers to that question. For Kant, there is a deep difference between time and becoming. Time is not a property of objects. Time precedes and structures our experience of

[4] Cf. David R. Griffin (1986).
[5] Newton's second Law is invariant under the transformation t→ -t.
[6] From now on, we will consider that the terms of *change* and *transformation* refer to the various kinds of species that constitute becoming.

outer objects. Time does not exist in the objects themselves but only in our manner of perceiving them. Time, as a medium, is what makes becoming possible. For this reason, time stays still and does not change: "*All appearances are in time, in which, as substratum (as persistent form of inner intuition) both simultaneity as well as succession can alone be represented. The time, therefore, in which all change of appearances is to be thought, lasts and does not change*[7]". Time is the neutral and motionless medium in which things become. Against Kant, Hegel will claim that time is nothing but becoming : "*But time itself is this becoming, […], the Chronos who gives birth to everything and destroys his offspring*[8]". The consequences of this identification of time and becoming is the impossibility to think their encounter but also the unreality of time whom McTaggart, right-wing Hegelian, will be the most famous representative.

These questions are also of crucial importance in physics and are closely related to the debate on the relational versus substantival nature of time[9].

3. Substantival time versus relational time

For a long time, physics has struggled between two different conceptions concerning the nature of space : substantivalism versus relationalism. If space is to be considered as an entity, then space exists by itself and physical entities move *in* space. Newton's absolute space as well as Minkowski's spacetime are substantival conceptions of space. In a relational perspective, space is just a convenient name for talking about the relationship between physical entities. In this case, position and motion of a physical entity are not to be referred to an absolute stage but have to be considered relative to other physical entities. Space is no more than the contiguity relation between objects.

Is time substantival or relational in nature ? Newton's absolute time is the archetype of a substantival conception : it is not affected by the events of the universe and constitutes the objective frame in which physical entities become. His homogenous flow permits the objectivity of becoming. Furthermore, a temporal vacuum, a period of time in which nothing happens, is possible : the entire motions of the universe could cease, Newton's time would theoretically be the tool capable of stating how long this absence of change has elapsed[10].

Leibniz has constructed his relational theory of space and time against Newton's conceptions. For Leibniz, space and time are just relations. Space is the order of coexistences while time is the order of successions. Space and time have no ontological values but a logical value : the one of an order relation. For the relationalist, time does not exist independently of change and becoming. Consequently, a temporal vacuum is impossible. The substantivalist will affirm the possibility of a temporal vacuum, because time is independent of becoming or change. For an absolutist, there can be time without change.

4. Time and becoming in Physics

The claim that time differs from becoming can be seen from two different perspectives. In the first one, time is a container or a frame. Time is the scene from which universal mobility is examined. If time is the unchanging cradle of becoming, then it is legitimate to think that things evolve in time. As a frame, time guaranties objectively the only rhythm of becoming. Newton and Kant represent the alternative objective/subjective or material/formal

[7] *Critique of Pure Reason* (1998, p.300), First analogy of experience, B225.
[8] *The Philosophy of Nature* (2004, p.7), §201.
[9] In physics, the term *becoming* includes less notions than it does in philosophy. From now on, becoming will be synonymous of evolution or simple change.
[10] Cf. Sydney Shoemaker, "Time without change".

of that theory. The second perspective is the one of Leibniz who sees time as the order of becoming. On one hand, with Newton and Kant, time introduces a form of transcendence relatively to becoming ; whereas with Leibniz, one can talk of immanence. Those two different perspectives on the relations between time and becoming differ ontologically but agree on one topic : the order of becoming, whether it is transcendent or immanent, exists and is unique. In other words, both for Leibniz and Newton, the universe as a whole evolves at a one and only pace.

It is coherent to think that time has no empirical existence but only refers to a peculiar structure of change. For example, an orientation of becoming would refer to a direction of time or time's arrow. This leads logically to the following questions concerning the relation of time and change. Is there one or various orders in the successions of events ? Could it be possible, that the structure (or the different structures) be determined relatively to different scales of magnitude or different level of energy ? Could the structure be emergent, and consequently that time emerges from becoming ? In this optic, timelessness would only indicate the absence of order or structure and consequently would lead to the idea of pure becoming or pure change, i.e change without time.

It clearly appears that causality plays a central role in the determination of the relationship between time and becoming. Can we claim that below time there is change, itself determined by causality ?

Finally, how one is supposed to proceed to discover these structures ? The idealist strategy takes from time to becoming, i.e concludes from the properties of time, the ones of becoming. This strategy is the one of a philosopher like Kant but also the one of a physicist like Costa de Beauregard. As we will show in the next section, this position is untenable because it commits the fallacy of misplaced concreteness. The opposite strategy is to start with becoming to explore its various structures, to then build one or various figures of time. This empiricist strategy is the one of a philosopher like Bergson but also a physicist like Carlo Rovelli.

5. The ambiguities of time and becoming

There is many misunderstandings within the relationship between time and becoming. Thus, when a philosopher like Bergson claims that time is the essential feature of our world, he means time as becoming, certainly not time as a frame or time as an order. Conversely, history has seen physicist denying becoming because irreversibility was absent of time as a frame. Moreover, a semantic vagueness penetrates our two concepts : the word *time* sometimes designates *becoming* (as in the sentence "time flows"), and sometimes refers to the *structure of becoming* (time-order or time-frame), as in the sentence, "things evolve in time".

Let us look again at the naïve structure of becoming that we were mentioning earlier. It would appear legitimate to imagine its elaboration as follows. A certain experience of change, relative to a distinctive physical scale and energy level, lead us to attributing a structure to that experience of becoming : closed past, moving present, open future. The Newtonian conceptualisation of time by a linear and reversible parameter, comes on top of it. Newton's absolute time is then the result of a double modelling : first, the one of our daily experience, next the one of the physicist. As noticed by Jean-Marc Lévy-Leblond[11], this time is not an objective time, it is a time objectivized, that one must be careful not to reify. Time is not the linear axis that we draw on graphs.

We see now that the process that reduces our experience of becoming to the one of a variable *t*, to next claim that this experience is an illusion, is hardly justifiable. In the same way, those thinkers and physicists, who think that, because certain physical laws are invariant

[11] Cf. Jean-Marc Lévy-Leblond (1996).

under the transformation $t \rightarrow -t$, irreversibility is an anthropocentric illusion. These misapprehensions originate in what Whitehead called "*the fallacy of misplaced concreteness*" : "*The fallacy is to treat the abstractions from certain things - abstractions focused on because of certain interests and methods - as if they were the concrete things themselves. It is to treat the map as if it were the territory, assuming that what is not on the map is not in the actual terrain itself*[12]". Isn't there something analogous, when in physics, one forgets that the variable *t* that we find in physical laws is an abstraction, to then claim that this variable describes the temporal structure of reality itself ? The abstractness of becoming in Newton's theory is forgotten and treated as if it could be equated with the becoming of reality itself.

If we now analyse this "*fallacy of misplaced concreteness*", we realise that it comes down to replacing change by space or number, and in the meantime, forgetting or not realising the process that makes the substitution. In other words, those double modelling of time, time-order and time-frame, are of numerical or spatial nature[13]. This leads to the question : is it possible to model time other than with the use of quantitative multiplicity ? Can we "*represent time without turning it into space*[14]". This question is at the heart of Bergson's philosophy of duration.

6. The spatialization of time

6.1. Quantitative and qualitative multiplicity

Bergson's philosophy is an attempt to show that physics profoundly misunderstands the nature of time and never deals with authentic time or becoming : what Bergson calls duration. By duration, the French philosopher means essence of time and thinks that time's main attribute is invention, that is "*continuous creation of unforeseeable novelty*[15]". Commentators have named this principal characteristic of duration *virtuality*.

In the second chapter of *Time and Free Will: An essay on the Immediate Data of Consciousness*, in order to show the difference between space and duration, Bergson sets up a distinction between quantitative multiplicities and qualitative multiplicities. On one hand, you have space and number. Space is homogeneous, quantitative and actual. Take the number "500" as an example of a quantitative multiplicity. Its actuality refers to the fact that, one perceives without counting them the "500" multiple of 1. Its homogeneity refers to the fact that for elementary arithmetic, there is no difference of nature between the elements of that multiplicity but a difference of degree.

On the other hand, you have duration which is in total opposition to space. Duration is heterogeneous, qualitative and virtual. The qualitative multiplicity is not made of homogenous element. This means that there is a difference of nature amongst its elements : "*duration properly so called has no moments which are identical or external to one another, being essentially heterogeneous, continuous, and with no analogy to number*[16]".

In order to understand duration as invention, Bergson resorts to another distinction often mixed up with the first one. This second distinction is between two couples : actuality and virtuality on one side ; possibility and reality on the other. Virtualities become actual and possibilities are realised. There is a relation of resemblance between possibility and reality

[12] Cf. David R. Griffin (1986, p.6).
[13] This is even more true concerning time as a frame. Indeed, Leibniz theory of relational time is a prisoner of a classical, that is non-relativistic, conception of causality. But in other relational theory of time, where appears the idea of change without time, this dependency on quantitative multiplicity is far less obvious since, the concept of change without time can be seen as change without frame but far more, change without order.
[14] Lee Smolin (2006, p.256-257).
[15] Bergson (1946, p.91).
[16] Bergson, (1996, p. 120).

whereas the actual does not resemble the virtuality it is incarnating. The latter explains why creation is duration's essential attribute and the idea of creative present and open future.

Man as the universe become but not according to the model of time-frame or time-order but in accordance with the mode of qualitative multiplicity

6.2. Duration and simultaneity

In 1922, Bergson publishes *Duration and Simultaneity*, a book in which he compares his own conception of duration to time in special relativity. We find in this book two major criticisms against special relativity. On one hand, Bergson says that in Einstein's theory, there is a confusion between reality and possibility, since, for Bergson, proper times are real while improper times are fictitious. On the other hand, Bergson claims that special relativity mixes up the qualitative and the quantitative multiplicities. Even more, he claims that the slowing of clocks in the twin pseudo-paradox is not real.

6.3. Returning to Bergson's original intuition

On several occasions, Bergson reminded what had been the starting point of his philosophy : "*It was the analysis of the notion of time, as that enters into mechanics and physics, which overturned all my ideas. I saw, to my great astonishment, that scientific time does not* endure*, that it would involve no change in our scientific knowledge if the totality of the real were unfolded all at once, instantaneously and that positive science consists in the elimination of duration*[17]". Bergson's main opinion is that when physics talks about time, it does not talk about duration but about a very poor conception of time, what he calls spatialized time. Physics substitutes to becoming understood as invention and "*continuous creation of unforeseeable novelty*", time-measure or time-length[18]. Spatialized time is the measurable time, symbolized by the variable *t*, that occurs in physical formulae. It can not shed any light on the nature of becoming as it is the ghost of space. Spatialized time is a quantitative multiplicity in which duration has been eliminated. This is striking if one considers the representation of time as an horizontal line : this idea of closed past, creative present and open future has disappeared from this representation. Physics replaces succession, duration's attribute, by juxtaposition, space's attribute.

In the light of this analysis, one sees that the French philosopher criticized relativity and Minkowskian spacetime for having invented a new way of spatializing time. But we know that Bergson's analysis of special relativity are wrong : there is no absolute simultaneity, the distinction between proper and improper times is legitimate and the slowing of clocks is experimentally very well established.

Milič Čapek, philosopher of physics and Bergson's commentator, has produced a series of arguments with the objective to put into perspective Bergson's conclusions. He tried to show that GR was realizing more profoundly a dynamisation of space rather than a spatialization of time[19] and that : "*Bergson was opposed to the idea of an inert container of physical becoming*". This is a crucial point. Bergson refuses the idealist strategy that we were mentioning earlier : time-frame or time-order cannot dictate becoming's properties. By

[17] Bergson to William James, May 9, 1908.
[18] Lichtenberg, an 18e mathematician, physicist and polemicist, was a precursor to Bergson as this little anecdote shows: " When on Friday evening the 3rd June 1769, Venus was expected to pass in front of the sun, we got organized to see her and we saw her indeed passing at the right time, but when the 8th July the princess of Prussia was expected to pass in front of Göttingen, we waited for her till midnight ; she only came in the morning at 10 am".
[19] Čapek, (1971, p. 314).

duration, and his criticism of spatialized time, Bergson means that the essential feature of reality is change. Things change and evolve but they don't change in time : "*There are changes, but there are underneath the change no things which change : change has no need of a support*[20]". Surprisingly, this claim could be the one of a relativist.

7. Time-parameter and time-coordinate (or time-dimension)

Albert Lautman was a French philosopher, born in 1908 and executed in Bordeaux in 1944. His contribution to the philosophy of mathematics and to the philosophy of time is still to day unrecognized. In an essay on the problem of time, published in 1946, he explains the necessity to distinguish in physics the time-parameter from the time-coordinate. Let us consider the following three statements : 1. Time flows in one and only direction 2. Objects persist through time : time's continuity permits objects' perdurance. 3. Dynamical variables evolve according to time. As shown by Lautman, the first two statements refer to time as a dimension whereas the third refers to time as a parameter. Can we identify the parameter of evolution, which one finds in the laws of nature, to time understood as an entity by itself with its properties of irreversibility and continuity ? The parametrization according to time is one of the major successes of classical physics[21]. However, does this time-parameter naturally leads us to the concept of time-dimension, as for example in Newton's theory ? Classical physics was naturally led to see the same entity in the time-parameter as in the time-dimension. But because of general covariance, this implicit identification is lost in GR.

9. The disappearance of the time-coordinate and the emergence of time in quantum gravity

In classical physics, systems evolve according to a time-parameter whose properties are dictated and guaranteed by Newton's absolute time-dimension. In special relativity, clocks measure proper time along inertial trajectories. This proper time is based on Minkowski's metric. Consequently, in classical physics as in special relativity, the evolution rests on a background and non-dynamical parameter. In other words, the time-parameter according to which systems evolve is reduced to the time-dimension (absolute time or Minkowski's substantival spacetime). The result is a spatialization of change and the occultation of its real nature.

This situation changes radically in GR. Because of general covariance, the time-coordinate that appears in $g_{\mu\nu}(x,t)$ has no physical significance. As clearly shown by Carlo Rovelli, GR predicts correlation between partial observables but not physical variables with respect to a preferred time *t*. Change is not described in terms of evolution in time but in terms of relative evolution between dynamical variables. In GR, the time-coordinate disappears and evolution is understood relationally.

In the light of what has been examined in the previous sections, one must see that the disappearance of the time coordinate and the relational understanding of evolution is at the same time a rediscovery of change and becoming in physics.

Evolution in classical mechanics also deals with dynamical variables with respect to other dynamical variables but when one compares this set of variables, one can easily verify that these observations fit with evolution in *t.* However, Carlo Rovelli argues that this equivalence between relative evolution and evolution in time is scale dependent and is dropped at the Planck scale : "*In particular, it gives us confidence that to assume the existence of the* unobservable *physical quantity t is a useful and reasonable thing to do. Simply : the*

[20] Bergson, (1946, 147).
[21] Lautman showed that the parametrization could in principle be done with any other independent variable.

usefulness of this assumption is lost in quantum gravity. The theory allows us to calculate the relations between observable quantities, such as A(B), B(C), A(T_1), T_1(A), …, which is what we see. But it does not give us the evolution of these observable quantities in terms of an observable t, as Newton's theory and special relativity do. In a sense, this simply means that there is no good clocks at the Planck scale[22]*."*

The disappearance of time at the Planck scale has to be understood as the absence of a time-frame but more radically as the absence of a time-order. How then is one supposed to understand evolution at the Planck level ? Obviously, things evolve but they don't evolve in time : there is change without time, i.e pure change. In this context, the thermal time hypothesis explores the mechanism of its emergence from such a timeless level : time emerges from pure becoming.

Conclusion----------

We have examined various questions : the dilemma between essential temporality and timelessness, the relationship between time and becoming, the spatialization of time and the distinction between time-parameter and time-coordinate. It appears now that the problems are related : the reduction of the time-parameter to the time-dimension is concurrently a spatialization of becoming and the occultation of time's nature : change.

The fact that the time-coordinate in GR has no physical significance, the relational understanding of evolution in GR that follows, and the emergence of time in Quantum Gravity from a timeless level, do not picture a Parmenidean and changeless world[23]. To the contrary, it brings back into favour the concept of becoming. In doing so, it does not commit the fallacy of misplaced concreteness and gives an *a posteriori* answer to Bergson's criticism of time in physics. Finally, it pictures a world of processes and events in which dynamics does not refer to an external parameter *t* but is intrinsically built into the systems. In this framework, the world is inherently dynamical.

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[22] Rovelli (2004, 30).
[23] Like in the picture proposed by Julian Barbour .

BIBLIOGRAPHY

- BARBOUR Julian,
  - "The timelessness of quantum gravity I & II", *Class. Quantum Grav*. **11** (1994), 2853-2897.
- BERGSON Henri,
  - *Time and free Will : an Essay on the Immediate Data of Consciousness*, Kessinger Publishing, 1996 (1889).
  - *The Creative Mind : An introduction to Metaphysics*, Wisdom Library, 1946 (1934).
- ČAPEK Milič,
  - *Bergson and Modern Physics*, Boston Studies in the Philosophy of Science, **VII**, 1971, D. Reidel Publishing Company.
- CLEUGH Mary F.,
  - *Time and Its Importance in Modern Thought*, Methuen, 1937.
- COSTA DE BEAUREGARD Olivier,
  - *La Notion de temps : équivalence avec l'espace*, Vrin, Paris, 1983.
- GRIFFIN David R. (ed.),
  - *Physics and the ultimate significance of time*, State university of New York Press, 1986.
- HEGEL Georg Wilhelm Friedrich,
  - *The Philosophy of Nature*, Kessinger Publishing, 2004 (1817-1830).
- KANT Immanuel,
  - *Critique of Pure Reason*, Cambridge University Press, 1998 (1781-1787).
- LAUTMAN Albert,
  - *Les mathématiques, les idées et le réel physique*, Vrin, 2006 (1933-1944).
- LÉVY-LEBLOND
  - « Quel temps fait-on ? », *Le temps et sa flèche*, éd. Étienne Klein & Michel Spiro, Champs-Flammarion, 1996.
- POINCARÉ Henri,
  - *The value of Science*, Dover, 1958 (1905).
- REICHENBACH Hans,
  - *The Direction of Time*, Dover, 1999 (1956).
- ROVELLI Carlo,
  - *Quantum Gravity*, Cambridge University Press, 2004.
  - "Forget time", FQXi contest on the Nature of Time, 2008.
- SHOEMAKER Sydney,
  - "Time without change", in Robin Le Poidevin&Murray MacBeath (eds.), *The Philosophy of Time*, Oxford University Press, 1993.
- SMOLIN Lee,
  - *The Trouble with Physics, Houghton Mifflin Company, 2006.*
- WHITROW G.J.,
  - *The Natural Philosophy of Time*, Clarendon, 1980.