THE PHILOSOPHICAL IMPLICATIONS OF EINSTEIN'S RELATIVITY THEORY

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"The struggle to widen our horizon and to go deep into our knowledge, is one of those absolute objectives without which it seems impossible for any thinking individual to have a conscious and positive attitude toward life. The true essence of our struggle for knowledge is made up, on the one hand, from the attempt to embrace the whole width and complex variety of the human experience, and, on the other hand, from the search for simplicity and for brevity in their essential foundations."[1]

The originator of the Special and General Theories of relativity,[2] Albert Einstein exerted a significant influence on his and all successive generations. His intellectual endeavour had great repercussions on many a field of thought, from mathematics to metaphysics. In his days, Einstein unceasingly advocated the attitude of critical rationalism, the critical search for error. His most important contribution being obviously that by which he taught us that Newton's cosmology, overwhelmingly successful due to its incredible survival of the most severe tests, may well be mistaken.

In the following paper, I suggest we first briefly pass over Einstein's life, and successively go into some philosophical implications of his theories. The attempt is to bring out Einstein's challenge to philosophy.

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1. From the message sent by Einstein in occasion of the 42nd meeting of the Società Italiana per il progresso delle Scienze, held in Lucca, 1950; published in *Albert Einstein: Idee e Opinioni* (henceforth recalled as *IDEE*) (ed. by C. Seeling) (Schwarz Editore; Torino 1965) 331-332.

2. Henceforth recalled as STR and GTR respectively.

Einstein

Born of Jewish parents in Ulm, Germany, in 1879, Einstein's first studies in theoretical physics are held in Milan. Later he studies mathematics and physics at the Swiss Federal Polytechnic in Zurich. It is in Bern, working at a patent office, that Einstein first meets intellectual success. Studying hard, in 1905 he is capable of publishing noteworthy investigations in the field of physics. The *Annalen der Physik* gives voice to four of his papers, together with memoirs on special relativity, which immediately give him widespread attention. His main thesis therein holds that radiation has a corpuscular as well as wavelike aspect. The articles mark the presentation of the *photon* (the light corpuscle), thereby superseding Planck's theories of 1900. But Einstein's main breakthrough that year was in another field. Publishing two papers, he launched his STR, thus establishing one of the main landmarks in science. Therein, Einstein rejects the ether concept (that medium providing the standard of absolute rest), a notion so fundamental to Newton's cosmology. Later, Einstein would write: "By way of the STR, affirming the equality of all the so-called inertial systems by the formulation of natural laws, I was immediately faced with a question. Briefly it would be like this: Does there exist also an equality between the systems of coordinates? In other words: if it is not possible to attribute to the concept of speed but a relative sense, why should we insist in continuing to consider acceleration as an absolute concept?"[3]

It actually seemed incredible that Newton's solid construction should go down like a pack of cards. However, Einstein's critical investigations, guided by simple, staunch questions, did open up the way to a new conception of the world and the universe. 1905's intuitions shall be henceforth expounded and developed, especially up to the formulation of the GTR, but enough not only to degrade Newton's high stand in science, but also to undermine any absolutist theory regarding reality.

In 1927, the year of the 200th anniversary of Newton's death, Einstein would say: "With no equal, before or after, Newton determined the course of thought and study in the West. He was not simply the genial inventor of methods destined to revolutionize the field of science. He was capable of dominating the empirical material of his time. His spirit extraordinarily showed itself to be ingenious in the specific analysis of mathematics and physics (...).[4]

3. From the notes on the origin of the GTR; published in *IDEE*, 268.

4. See *IDEE*, 240.

The generalized theory of relativity constitutes the ultimate development in the evolution of the theory (of motion). Quantitively, it modifies but little of the theory of Newton, but qualitatively, it introduces much more profound changes."[5]

The years following the publication of the STR, proved to be crucial for the 35-year old Einstein. First at the University of Zurich, then at the German University of Prague, and finally at the Federal Polytechnic of Zurich, he teaches theoretical physics. Before dedicating himself exclusively to scientific research, he is made member of the Royal Prussian Academy of Sciences and the Kaiser Wilhelm Gesellschaft. "The theoretical method," he held in those years, "is founded on the need to take as a starting point some general hypothesis, called "principles", from which it is possible to deduct consequences. Our activity is thus accomplished in two ways: to find, first and foremost, the principles, and successively to develop the consequences which follow (...). The investigator has to listen to the secrets of nature, find out the general principles, having as his objective the formulation of the general elements of the complexities of empirical facts."[6] In this way, Einstein is establishing the foundations of the new approach to scientific research. It is this which in later years proves to be of great epistemological importance in the field of philosophy. Einstein believed in the method and its implications, and effectively made use of it in his investigations. When in August 1916 Einstein viewed his famous GTR, he was anxious to set it to the test. The GTR was an advance over the classical gravitational theory of Newton, and thus could hardly be taken seriously. It announced the deflection of light in a gravitational field. The tests made to the GTR were more than welcome to Einstein. It clearly involved great risk.[7] If observation (by Eddington) showed that the predicted effect is definitely absent, then the theory would have been simply refuted. The theory, in that case, would have been incompatible with certain possible results of observation. The system employed here is not that of verification, but that of falsification: no attempt is made to verify the theory, but, on the contrary, to disprove it.

When the theory was proved right (in 1919), Einstein gained world-wide fame. The GTR held that the laws of nature should be expressed in a form that

5. *IDEE*, 245.

6. From Einstein's inaugural speech at the Prussian Academy, 1914; in *IDEE*, 210 and 211 respectively.

7. See on this point, K.R. Popper, *Conjectures and Refutations: the growth of scientific knowledge* (London 1989) 35-37.

is the same for any choice of space and time coordinates, and this was demonstrated in a theory that was purely geometrical. "Without geometry it would have been impossible to formulate the theory of relativity. Without it the following reflection would have been impossible: in a system with a general relational reference to an inertial system, the laws of solid bodies do not correspond to the laws of the Euclidean geometry, following the contraction of Lorentz. This means that if we do not accept the systems of non-inertia on the basis of equality, we have also to abandon the Euclidean geometry. Without this latter interpretation the decisive move for the acquisition of the general covariant equations would have certainly been impossible."[8]

The 3-D Euclidean geometry which was for ever made use of for an intelligible understanding of the universe thus gave way to a new conception. These far reaching results came after the actual publication of the GTR. At the time, the GTR seemed to be simply a different result following a different combination of age-old laws. "In the first place, the GTR is due to the numerical equality, picked up by experience, of the inert mass and of the mass weight of bodies. This is basic. However, it is something classical mechanics has failed to explain. We arrive at it by extending the principle of relativity to the systems of coordinates by acceleration relative to one and the other. The introduction of systems of coordinates to the relative acceleration in relation to inertial systems necessarily leads on to the appearance of gravitational fields in one and the other."[9]

The further understanding of the theory pressed home the fact that the STR became the limiting form of the GTR in situations where gravitational effects are negligible.[10] Both theories together presented a comprehensive picture of the new-founding science. The principle of relativity became the fundamental starting point for the study of physical phenomena. In this way, Newton's laws were rejected, together with his concept of time (and, in particular, that of simultaneity).

Einstein's critical powers had made a great effect on the world of phenomena. He affronted the field with an inquisitive air and a passionate love for truth. Every riddle encountered called in him serious, though incredibly

8. Einstein at the Prussian Academy of Science, 1921; in *IDEE*, 222-3.

9. Einstein at King's College, London, 1921; in *IDEE*, 234.

10. See the further technical points offered, relating to physical theory, in N.R. Hanson's "Philosophical implications of Quantum Mechanics", in Macmillan's *The Encyclopedia of Philosophy*, vol 7, 44-46.

simple, profound thought. In this Einstein was following in the footsteps of two great philosophers, Hume and Mach. Hume with his criticism of the traditional common-sense assumptions and dogmas; Mach with his criticism of Newton's absolute space. "The advantages of constructive theory," Einstein would say,[11] "are completeness, adaptability and clarity. Those of the theories of principles are the logical perfection and the certainty of the fundamental principles themselves. The theory of relativity belongs to this second class. To affirm its essence it is necessary first of all to understand the principles on which it is built (...). The theory of relativity resembles a building with two stories: the special theory and the general theory."[12]

Einstein understood (quite against the conception of Newton) that if velocity increases, inertial mass of a body increased too. This meant that no particle of matter can ever attain the velocity of light. Mass depends on velocity, which means that mass and energy are manifestations of the same fundamental entity. This was confirmed by subsequent nuclear physics. In equation form this result took the by-now famous appearance of $E=mc^2$ (energy E is the result of mass m times twice the speed of light c).

In 1917, Einstein arrived at a new world model, a finite but unbound universe (the so-called "Einstein universe"). This marks the beginning of modern theoretical cosmology. However, at the very time, Einstein was continually preoccupied with giving the theories ever more simple forms. The laws of his physics had to be logically perfect, well-founded, *and* simple. In the Berlin Society of Physics he had said: "The ultimate end of the physician is to arrive at universal elementary laws which permit the reconstruction of the universe by a deductive way. There is no logical path which leads to such universal laws. Only intuition, founded on experience, can lead us to them. Such an uncertain methodology may give the impression of the existence of an imprecise number of systems of physical theory all equally justified. Undoubtedly, this is a correct impression from the point of view of theory."[13]

11. Einstein's article in the *London Times*, November 28th, 1919; in *IDEE*, 217.

12. See A. Grunbaum, "Philosophical significance of relativity theory", *The Encyclopedia of Philosophy*, vol.7, 133.139-140.

13. The year was 1918; see *IDEE*, 215. In the *Journal of the Franklin Institute*, vol.CCXXI/3(March 1936) Einstein spoke briefly on the same subject: "There does not exist an inductive method which can lead to the fundamental concepts of physics. The failure in comprehending this constitutes the fundamental philosophical error of many men of study of the 19th century. This was probably why molecular theory and the theory of Maxwell are affirmed relatively very late. *Logical thinking is necessarily deductive.* It is based on hypothetical concepts and axioms. How can we

In 1922, Einstein is awarded the Nobel Prize. At this point he is invited all over the world to meet people, and give conferences. In the early thirties he was visiting lecturer at the California Institute of Technology. And when the ascent of the Nazis was approaching, he became, in 1933, professor at the Institute of Advanced Study at Princeton. America became for evermore his new home. In 1941 he acquired American citizenship. He died in America in 1955. An aphorism[14] Einstein himself wrote maybe is enough to explain his existence: "The joy of looking and of understanding is the most beautiful gift of nature."[15]

Philosophical implications

As a way of introducing the philosophical implications, I shall say a word on Einstein's Quantum Theory in general.[16] By presenting the QT, Einstein showed that microphenomena prove themselves to us as dual in nature. Quantum mechanics is presented as a single, unified theory, to be true. But it is a unity within which (i) wave conceptions (field/distribution/probabilistic conceptions) and (ii) particle conceptions (point mass/singularity/granular conceptions) are equally fundamental in explaining and predicting the associated phenomena.[17] The limits of the QT can be placed on two levels. First, Einstein teaches us that quantum statistical mechanics requires that nothing be said of the micro-constituents of an ensemble beyond what can be said of the macro-behaviour of the ensemble itself. In the second place, we have Einstein insisting that QT is built upon uncertainties even more comprehensive then that concerning position and momentum. Energy and time and number and phase constitute equally pervasive structural features of quanta mechanics, each involving analogous uncertainties. *Nature, then, is fundamentally indeterministic.* Elementary particles are, ontologically, always in partially

expect to choose the axioms, hoping for the confirmation of the consequences derived from them?". For this extract see *IDEE*, 287 (italics mine).

14. Written for the commemorative publication in honour of Leo Baech in 1953, see *IDEE*, 39.

15. At this point, I would like to call attention to the so-called "Einstein myth". More than one writer today rightly holds that Einstein is not history, Einstein is myth. See in this regard J.-M Levy-Leblond, "L'albero che nasconde la foresta: a proposito del mito einsteiniano", *L'Opera di Einstein* (edited by U. Curi) (Ferrara 1989), 108ff. The reader will not fail to note Levy-Leblond's dislike of Einstein. The article, I think, should be read with a pinch of salt.

16. Recalled as QT.

17. See Hanson, "Quantum mechanics", 44.

defined states, without exact position or energy. The constituents of the atom are not and may not be endowed with sensory qualities at all.[18]

Such comments already bring us to some problematics in the field of philosophy. For example, how can the basic elements of the physical world essentially exist void of any quality? However, before going into such questions, a further consideration must be made. It is well known that Bohr and most of the quantum physicists hold that the ultimate laws of nature are not causal or deterministic. In this they are supported also by some sympathizers of Einstein, at least on a philosophical plain.[19] Einstein, in fact, held that the physical reality is a 4-D space-time continuum in which events are already determined, the passage of time applying only to the human consciousness as it becomes aware of different events. The physical theory of invariant quantities, then, points to qualities that are unaltered by transformative formulas from one frame of reference to another. This shows that the axioms of physical theory, although they must be tested empirically, are not automatic inferences from experience but are free creations of the human mind, which is guided by considerations of a mathematical nature.[20]

Fundamentally, then, we have different interpretations of quantum physics. Basically, where Einstein-Podolsky-Rosen differ from Bohr-Heisenberg is precisely on the incompleteness of quantum physics. Einstein's position held that it still does not include certain significant causal factors responsible for indeterminacy. Notwithstanding the differences, the realist philosophy of science is being seriously concerned[21] with the claim that the structure of the theoretical concepts corresponds to some extent with the structure of their

18. See Einstein's own discussion on the fundamentals of theoretic physics in general, published in *Science*, Washington D.C., May 24, 1940; in *IDEE*, 307-309.

19. Popper, for example, was one of them. In his *Conjectures*, 61, we read: "There are a number of further problems connected with the interpretation of the formalism of a QT. In a chapter of *The Logic of Scientific Discovery* I criticized the "official" interpretation, and I still think that my criticism is valid in all points but one: one example which I used (in section 77) is mistaken. But since I wrote that section, Einstein, Podolsky and Rosen have published a thought-experiment which can be substituted for my example, although their tendency (which is deterministic) is quite different from mine. Einstein's belief in determinism (which I had occasion to discuss with him) is, I believe, unfounded, and also unfortunate: it robs his criticism of much of its force, and it must be emphasized that much of his criticism is quite independent of his determinism."

20. See the interesting comments on the quantistic field by D.W. Sciama in "Einstein e la termondinamica dei buchi neri," in Curi (ed), *Opera di Einstein*, 178-180.

21. For the philosophical implications of the QT's wholism and non-locality, see R.J. Russell, "Quantum physics in philosophical and theological perspective", *Physics, Philosophy and Theology*, (ed. by R.J. Russell) (Vatican City 1988) 351-354.

references in nature. This may be certainly understood within the context of truth as correspondence. However the challenge goes also into the claim of convergence. In this sense quantum physicists hold that the sequence of those terms generated by successive theories stand in increasingly more accurate correspondence to those structures.

The more or less definitive formulation of mechanical quantistics leads us to the concept of relativity in atomic physics. Einstein held that the atom and the field of radiation have to be considered together, as part of the same single physical system.[22] Atomic and field energy, and their mutual interaction, have to be observed within the context of a complex energy system and mass relativism. What we actually have here is the concept formation of the theories of relativity in respect to the definition of their basic and essential terms. In the long run, it will be seen that Einstein is thus positing some lofty philosophical questions, such as: (i) What is the significance of scientific knowledge?[23] (ii) Can we have objective information about the world? (iii) What is the real nature of physical interactions (causation) between phenomena? and (iv) What is the proper function of scientific theories? Such questions call for answers concerning basic concepts, such as, matter, energy, cause/effect, and "the external world". "According to me," Einstein would profess,[24] "nothing can be said aprioristically about the formation and interactions of concepts. The same holds about how we coordinate these concepts to sensible experience. Only success is the determining force which guides us to the creation of such an order of the sensible experience." And again:[25] "The objective of science is, on the one hand, to arrive at the most possibly complete understanding of the interactions between sensible experiences in their totality. On the other hand, it is to arrive at this latter objective with the use of the fewest primary concepts and relations possible (going as much as will allow the possibility of having a logical unity of the elements of the world, that is, saving logical elements). Science implies the totality of the primary concepts, that is, those concepts directly in relation with sensible experiences, and the propositions which they establish. In this very first phase of development, science is nothing

22. On the relation of quantum mechanics and relativity, see L. Gratton, *Cosmologia: la visione scientifica del mondo attraverso i secoli*, (Zanichelli; Bologna 1987) 316-321.

23. The question may be reformulated also in the following manner: What is scientificability? When can knowledge be named "scientific"?

24. From the *Journal of Franklin Institute*, CCXXI/3, (March 1936). Cf. *IDEE*, 273.

25. Same as note 24. pp.274-275.

but this. Our everyday thought is absolutely satisfied at this level, (...) but a scientific mind (moreover) demands logical unity."

A philosophical comprehension of Einstein's relativity theory (STR and GTR) will therefore have to go into epistemological and ontological considerations.[26] Philosophy is first and foremost interested in the fundamental basis of the theory, in the effort to establish a theory of the principles of the natural being.[27] The STR is generally considered to be founded on four main principles, each of which carrying philosophical implications.[28] In the first place, we have the concept of *movement*. This would include or point to other basic notions, such as, inertial systems, a point of stable reference (which is material), and the limits of velocity.

Secondly, the concept of the *absolute*. A basic notion implied herein would be the absolute velocity of light, which rises serious philosophical questions.

Next, the concept of *comprehensibility*. This is basic insofar as it refers to the relation of the principle of movement to the principle of the absolute light velocity. The concepts of change, and identical space — materiality and inertial mass — come to the fore.

Finally, the concept of the movement of *bodies*. Philosophical bewilderment at this point would be: What is a non-body? What is light, after all?

The GTR has three fundamental notions which, in relation to those of the STR, though precisely founded on them, have much more wide-reaching effects. These are basically three. The first is the concept of *generalization* which accepts non-inertia as a point of reference. This is directly in relation to gravitational force and phenomena, and its language, 4-D geometry.

Next, we have the concept of *real mass*, which is the cause of the gravitational field. This has to do with the space-time structure, and the "void" physics.

26. See the interesting criticism made by A. Eddington in *The Philosophy of Physical Science*,(Cambridge University Press; Cambridge 1939) 73-85. His criticism proves to be too emphatic in regards to the subjectivity of the theory in a rather personal way, more or less excluding a more generic kind of subjectivity.

27. D. Wandschneider's natural philosophy brought out such principles superbly. See his "Aspetti filosofici delle teorie della relatività speciale e della relatività generale di Einstein", in V. Curi (ed.), *Opera di Einstein*, 124-136.

28. E.L. Doriga has an illuminating discussion of these in his *El Universo De Newton y de Einstein: Introduccion a la filosofia de la naturaleza*, (Herder; Barcelona 1985) 161-172.

Finally, the principle of *equality* or inertia and gravitation.

Both theories, moreover, have a couple of presuppositions worth mentioning. The first is that of the *attraction* effect which explains the tendency of bodies to fuse under certain conditions. The second is the *determinative* effect of a complex mass present within a spacial-temporal structure.

Epistemologically, the aspect of subjectivity in relation to the theory of relativity is very much commented upon.[29] Time and space, truth, science and human knowledge all come into the picture. The crucial question would be: Is physical relativism equal to subjectivism? Can the theory of relativity be interpreted in a subjectivistic manner? Or even positively? Or yet relativistically (in the philosophical sense)? Does Einstein's theory have a purely formal and phenomenological value? Einstein himself considered the theory as confirming the objective and absolute value of human understanding and the natural human capacity to break the confines of immediate sense experience and sensible intuition. Einstein's principle of falsification is sufficient proof against this subjectivity and likewise against absolute theories. In reference to Einstein's trial and error method, Popper holds[30] that the difference lies not so much in the trials as in a critical and constructive attitude towards error; errors which the scientist consciously and cautiously tries to uncover in order to refute his theories with searching arguments, including appeals to the most severe experimental tests which his theories and his ingenuity permit him to design.

Ontologically, in relation to the nature of the physical world, the theory of relativity may offer more philosophical content. It is a clear statement against a mechanical comprehension of the world. Moreover, it casts precious light on the extension, the durability and the evolution of the universe, giving sufficient material for an explanation of its cause and life. The theory also finally rejects absolute time and space, as much as it demonstrated that they are not altogether abstract and mathematical, but are aspects of physical bodies. In relation to acceleration and velocity, or to action in general, the theory affirmed the constancy and the limit of the velocity of light, the final constant. It also rejected the unity and universality of physical time. Metaphysically speaking, this identification between the temporal and the spacial coordinates only reject the

29. See, for example, Eddington, *Physical Science*, 85-87; Grunbaum, "Relativity theory", 133; and F. Selvaggi, *Filosofia del Mondo*, (Rome 1985) 347, where a comprehensive bibliography on the subject is given.

30. *Conjectures*, 52.

existence of becoming and hence the fundamental distinction between being and becoming, between extension and movement.[31]

In conclusion, I would like to quote Einstein himself once more in a passage of considerable weight.[32] It is a passage which brings out the relation between theoretical science and philosophy, and the physical experiential foundation of human and scientific knowledge: "If one considers the proper object of the theory of relativity, it is worth while to note that such a theory does not have a speculative origin, but comes from a complete desire to adapt in the most suitable way possible the theory of physics with observable facts. It is thus not a revolutionary act, but rather a natural evolution in a direct line across the centuries. The rejection of certain concepts, which unto this day were considered unalterable, on space, time, movement, was not an arbitrary act. On the contrary, this was only imposed from the observation of certain facts."

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31. On this point, see Selvaggi, *Filosofia del Mondo*, 355.

32. Speech given at King's College, 1921; Cf *IDEE*, 233.

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