Einstein, the Method of Theoretical Physics and Reality

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This paper inquires into epistemological backbone of Einstein's approach to phenomena of Nature. In order to understand or even begin to investigate the work of a theoretical physicist, one needs to comprehend the language of his theory. This, in turn, requires a leap from our everyday dealing with the world. More precisely, an epistemological leap is needed, through which we are required to shed specific anthropomorphic elements comprised in our everyday thinking. This move can solely be done by recognition of philosophical issues that triggered the leap in physics in the first place. The paper should thus take us from the 'everyday' through philosophy to physics and back to philosophy, pointing out the consequences for how we perceive reality in each of these modes.

As Russell (1925) pointed out[i] *everyone knows that Einstein did something astonishing, but very few people know exactly what it was.* The theory of relativity, especially general theory of relativity, immediately captured philosophers' attention – numerous interpretations followed. Be it by representatives of Machian positivism, Kantians and neo-Kantians, logical empiricist, representatives of naïve realism, relativistic rationalism, common sense philosophy –part of or the totality of theory of relativity was dissected, criticized, interpreted and reinterpreted time and time again. Klaus Hentschel (1990)[ii] upon analyzing 2500 published texts as well as the unpublished ones dating from 1910 to 1930 concludes how this interest, due to the fact that each of the philosophical analysis is distorted by the interpretational framework of the philosophers' respective theories, led to incommensurable interpretations of one and the same theory. But one should not even begin to interpret this as an exclusive trait of this specific theory or the aforementioned approaches to it. Each philosophical interpretation always incorporates as a backbone a broader ontological and/or epistemological stance, even when unreflectively unconscious of it. This paper inquires into the epistemological presuppositions of Einstein's theory, trying to illuminate the impetus to his approach in theoretical physics while shedding a little light on the *astonishing thing* he did. It incorporates three intertwined lines of though, (i) pointing out the necessary epistemological leap from our everyday thinking needed to understand the concepts of theoretical physics while (ii) shedding a light on the scientific developments in early twentieth century, and (iii) their implications for what we call 'Reality' and our relation to it.

The opening lines of The Herbert Spencer Lecture which Albert Einstein delivered at Oxford, June 10, 1933, stress a revealing aspect in the approach of a theoretical physicist. Einstein[iii] states: *If you wish to learn from the theoretical physicist anything about the methods which he uses, I would give you the following piece of advice: Don't listen to his words, examine his achievements. For to the discoverer in that field, the constructions of his imagination appear so necessary and so natural that he is apt to treat them not as the creations of his thoughts but as given realities.*

On a slightly different note Cassirer (1921)[iv] points out the *unavoidable fate of the scientific approach to the world that each new and fruitful concept of measurement should be transformed at once in the thing-concept. (...) Each creative epoch of physics discovers and formulates new and distinctive measures for the totality of being (…) but each stands in danger of taking these preliminative and relative measures these temporarily ultimate intellectual instruments of measurement as definitive expressions of the ontologically real*.

These perils two authors aim to describe are not equivalent but they do overlap in a significant way which seems close to our pre-philosophical, pre-scientific everyday dealing with the world. Using the concepts borrowed from the world of sciences (or any concept whatsoever) in everyday life we rarely think about the origins or the meaning of these instruments of dealing with the world. When we talk about distances, times, mass, speed we think of these things as something completely outer, inherent to the outside world. We rarely think about inner workings in coming up with these measures. Furthermore, we see, smell, touch and taste – and we conclude about the world – not about our relation to it. Study of Nature arose out of these everyday sense perceptions, so the primitive system of physics was divided into optics, acoustics, and theory of heat[v]. In our everyday life we're close to the first physicists – for we conclude that the measures we use are derived completely from experience. This stance seems to have been still present in the stances of the classical theoretical physicist as it seems completely compatible with Newton's *hypothesis non fingo.* In Einstein's words *the scientists of those times were for the most part convinced that the basic concepts and laws of physics were not in a logical sense free invention of the human mind, but rather that they were derivable by abstraction, i.e. by a logical process, from experiments.* [vi]

But for those who choose the province of Experience to find the certainty of knowledge in physical laws, trap was already set by the philosophical skeptics. For the purpose of this paper solely Hume's analysis of the connection of causality will do, for it portrays clearly what happens when that line of thought is carried out to its definite philosophical consequences. If all our knowledge is derived from sense experience then in the relation of causality, the relation of constant conjunction is revealed for *contiguity and succession are not sufficient to make us pronounce any two objects to be cause and effect, unless we perceive, that these two relations are preserv'd in several instances*[vii]. The necessity we attribute to that relation is an act of Reason. But what could support our conclusion from past experienced instances of reoccurring 'cause' and 'effect' to future instances? Haven't we been wrong in establishing some of these connections[viii]? Certain knowledge we desire, collapsed thus into probability, and the notion of cause and effect into nothing but custom[ix]. Hume's skeptical approach to knowledge[x] leaves the classical physicist lacking the secure basis for extraction of unambiguous natural laws. Interestingly enough, Kant, trying to vindicate the certainty in knowledge, turns precisely to students of nature and mathematics for impetus to thought. He points out in the preface to the second edition of his *Critique of pure reason,* while trying to vindicate reason from Hume's devastating criticism, that findings of Galileo, Torricelli and Stahl shed a new light on the students of nature.

Sie begriffen, dass die Vernunft nur das einsieht, was sie selbst nach ihrem Entwürfe hervorbringt, dass sie mit Principion ihrer Urtheile nach beständigen Gesetzen vorangehen und die Natur nöthigen müsse auf ihre Fragen zu antworten, nicht aber sich von ihr allein gleichsam am Leitbande gängeln lassen müsse ; denn sonst hängen zufällige, nach keinem vorher entworfenen Plane gemachte Beobachtungen gar nicht in einem nothwendigen Gesetze zusammen, welches doch die Vernunft sucht und bedarf. Die Vernunft muss mit ihren Principien, nach denen allein übereinkommende Erscheinungen für Gesetze gelten können, in einer Hand, und mit dem Experiment, das sie nach jenen ausdachte, in der anderen, an die Natur gehen, zwar um von ihr belehrt zu werden, aber nicht in der Qualität eines Schülers, der sich alles vorsagen lässt, was der Lehrer will, sondern eines bestallten Richters, der die Zeugen nöthigt, auf die Fragen zu antworten, die er ihnen vorlegt.[xi]

If, as is clear from Hume's account, accidental observations do not converge into a necessary law, then assured knowledge is to be found in Reason itself. Principle of causality, then, is one of the *a priori* tools Reason approaches the Experience with, the same as the principles of geometry.

Kant's Copernican turn in seeking secure knowledge in the investigation of the faculty of Reason was not unknown to the physicists themselves. In fact, what Kant observed in the development of natural sciences and mathematics was, through the prism of his work, absorbed back into the very thought on Nature in even stricter and more self-aware terms. The first step in our epistemic leap needs to be thus the acknowledgement and reception of Kant's emphasis of the role of Reason. Theoretical physicist approaches the phenomena of Nature with a mathematical construction in hand, and while the experience can be the guide in the choice of that construction, and the criterion of its serviceability, it is no longer viewed a source of it[xii]. While in classical theoretical physics we still find the 'preliminative measures' transformed into ontologically real, each new stage in the development of physics, takes us further away from this notion that is close to our pre-scientific everyday conceptions of the measures. As Cassirer eloquently puts it in his survey of the progression of natural sciences, we find that with each new stage of development *what measures is separated with increasing distinctness from what is measured*[xiii] - through realization that principles and postulates do not represent the absolute properties of things, but a *free establishment of a certain standard and symbol of measurement*[xiv].

Einstein, while analyzing the method of theoretical physics through *the eternal antithesis of the two inseparable constituents of human knowledge, Experience and Reason*[xv]*,* stresses that it is Reason that provides the structure to the whole system. This is not to say that Einstein was a full-fledged neo-Kantian in his approach nor that understanding of twentieth century physics is the exclusive province of those that accept some form of Kantian approach to the study of nature. It does provide us with insight into the extent of awareness of the important philosophical epistemological issues Einstein possessed. He writes in *Remarks on Bertrand Russell's Theory of Knowledge* a comment on admiration of Hume's approach, as well as Kant's solution, but with a specific *proviso*:

Today everyone knows, of course, that the mentioned concepts contain nothing of the certainty, of the inherent necessity, which Kant had attributed to them. The following, however, appears to me to be correct in Kant's statement of the problem: in thinking we use, with a certain "right," concepts to which there is no access from the materials of sensory experience, if the situation is viewed from the logical point of view.[xvi]

The findings of natural and mathematical sciences progressed from the point on which Kant's critical conception of knowledge was based; Newtonian physics and Euclidean geometry were surpassed[xvii], so the *proviso* shouldn't surprise us. For Einstein, and the following passages should show the connection of this epistemological stance to his work in physics, *there are no final categories in the sense of Kant*[xviii] . Namely Einstein is referring to Kant's twelve pure concepts of understanding[xix], the preconditions of our dealing with the Experience, in which the necessity is embedded, i.e. *a priori* tools Reason approaches the experience with (as was noted earlier). He writes in his *Autobiographical notes: Hume saw clearly that certain concepts, as for example that of causality, cannot be deduced from the material of experience by logical methods. Kant, thoroughly convinced of the indispensability of certain concepts, took them just as they are selected to be the necessary premises of every kind of thinking, and differentiated them from all concepts of empirical origin. I am convinced, however, that this differentiation is erroneous, i.e., that it does not do justice to the problem in a natural way. All concepts, even those which are closest to experience, are from the point of view of logic freely chosen conventions, just as is the case with the concept of causality, the problem with which these inquiries concerned themselves in the first place.*[xx] Einstein's point is that all concepts used are to be treated in equal manner, as preconditions of understanding, free creations of Reason allowing us to claim order in the *datum* of Experience, i.e. difference Kant posits between empirical *a posteriori* concepts and the *a priori* is erased in a specific way. No concepts arise from experience; all concepts are posited on the Experienced. Writing about the formation of primary concepts in everyday thinking, empirical concepts which are the content of the first stages in the development of physical science he states that *in guiding us in the creation of such an order of sense experiences, success alone is the determining factor. All that is necessary is to fix a set of rules, since without such rules the acquisition of knowledge in the desired sense would be impossible. One may compare these rules with the rules of a game in which, while the rules themselves are arbitrary, it is their rigidity alone which makes the game possible. However, the fixation will never be final. It will have validity only for a special field of application.*[xxi] The list of categories applied, so to speak, will depend on the field of application; the extent of the Experienced Reason is providing order to. The emergence of order among the Experienced, reversely, serves as an indicator of 'serviceability' of the construction applied.

In the progression of science completeness of comprehension is sought in providing *logical unity in the world picture,* by the *use of a minimum of primary concepts and relations,* i.e. concepts directly and intuitively connected to sense experiences.[xxii] Simply put, the goal is to account for as much of the phenomena of Nature as possible, while adhering to the requirement of logical paucity of elements applied. The expansion of knowledge is thus parallel with the constant rising in the level of abstraction of the logical apparatus applied, which remains, for Einstein, a free construction of scientist's mind, though it must not lose its connection with the totality of sense experiences[xxiii]. For people in everyday thinking mode this abstraction tends to be incomprehensible, for it seems remote from their experiences and leaves them robbed of notions previously unquestioned, such as – to borrow the example from Einstein's own theory – simultaneity of events. For physicists, this higher level of abstraction means departure further from anthropomorphic elements[xxiv], and this is the definition of objectivity in theoretical physics. Though the logical construction cannot be separated from a specific physicist, its level of abstraction which unifies the ever expanding set of sense data is what assures departure from ambiguity of the primary concepts of sense experience. The strive for unity and copleteness in creation of systems to organize the phenomena, by Einstein's own addmission[xxv], might never find its definite realization, but it remains the quest of theoretical physics. It is precisely in this quest that we see the true accomplishment of Einstein's theory. Max Planck [xxvi] states that Einstein's conception *surpasses in boldness everything previously suggested in natural phenomena and even in philosophical theories of knowledge (…). The revolution introduced by this principle [xxvii] into the physical conceptions of the world is only to be compared in extent and depth with that brought about by the introduction of the Copernican system of the universe.*

This revolution was needed in natural sciences, for nothing short of a revolution could solve the impasse in which physics was bound by the disagreement of basic principles in classical system of mechanics and the foundations of electrodynamics. The contradiction in findings of these two disciplines of physics was, as Cassirer[xxviii] beautifully designates it in his portrayal of the developments in physics, a dialectical impetus to the development of theory of relativity. The apparent contradiction, as Einstein refers to it[xxix], was in the incompatibility between two principles – principle of the constancy of the velocity of light in vacuum[xxx], basic principle of electrodynamics, with the principle of special relativity in classical mechanics, namely the postulate that laws valid in reference inertial system K are equally valid in inertial system K' which is in relation to K in uniform translatory motion[xxxi]. Namely, the attempts to apply this principle of special relativity (in the restricted sense), in which equations of Galilean Transformation are used[xxxii] in electrodynamics was met with failure. Application of equations of Galilean Transformations in electrodynamics produces absurd results, because the values for the speed of light vary from one reference system to the next – even though the principle of the constancy of speed of light in vacuum should be equally valid in each system. To understand Einstein's move in placing these two apparently conflicting principles as axioms in his special theory of relativity[xxxiii], a bit of history of 19th century physics is required[xxxiv].

In 1851Hyppolyte Fizeau conducted an experiment measuring relative speeds of light in the flowing liquid[xxxv]. According to the theorem of the addition of velocities in classical mechanics, the speed of light in a flowing liquid should equal the sum of the speed of light in a motionless liquid and the speed of the liquid, as expressed in the following equation.

$$W = w + v$$

Fizeau's findings did show an increase in the speed of light, but only for a fraction of the speed of flow. More precisely the speed of light in the flowing liquid was

$$W = w + v(1 - \frac{1}{n^2})$$

where *n* is the index of refraction of the liquid, namely quotient of the speed od light in the vacuum and the speed of light in the motionless liquid.

$$n = \frac{c}{w}$$

This seemed to confirm the existence of the luminiferous aether, a medium for the propagation of light, more precisely aether drag hypothesis as proposed by A.J. Fresnel in 1818. Hypothesis was, basically, that the medium for the propagation of light is partially entertained by substance in motion. But an experiment in 1887 by Albert Michelson and Edward Morley seeking to point out the effects of movement of earth relative to aether (i.e. 'aether drift') failed[xxxvi]. From 1892 till 1904 H.A. Lorentz, seeking to explain away the results of this experiment, proposed an electron/aether theory in which aether is completely motionless, and hypothesized that bodies in movement relative to aether undergo length contraction (Lorentz-FitzGerald contraction[xxxvii]) and are susceptible to time dilatation (thus the introduced variable 'local time'[xxxviii]), as expressed in equations known as Lorentz Transformations:

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}},\ y' = y,\ z' = z,$$

$$t' = \frac{t - \frac{v}{c^2}x}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Simply put, it is the substance in motion that is entertained by aether. Null results in 'aether drift' experiments are obtained because the instruments of measurement undergo same contraction. While Lorentz's theory did succeed in explaining the contradictory results of Fizeau's and Michelson-Morley experiment it has two apparent shortcoming, namely it (i) presupposes the existence of aether (i.e. presupposes what it's trying to prove)[xxxix], and (ii) it led to two different notions of time – one mathematical ('local time' used in Lorentz Transformations) other physical (time in Galilean Transformations). In addition, the apparent contradiction between the leading principles of two branches of physics remained intact[xl]. Obviously this fact clashes with the ideas of unity and completeness of comprehension sought in physics. Under the influence of Hume's and Kant's philosophical ideas, Einstein's theory was purely axiomatic, accounting for the phenomena it seeks to explain, yet not positing anything as ontologically real. He managed to do away with the notion of aether, while uniting the aforementioned principles into a coherent system. As previously noted he uses them as axioms and devises a theory that would satisfy requirements of both principles. This could only be done by revising the physical notions of space and time, and Einstein consequentially robs them of their absolute values. Namely, in classical mechanics it was hypothesized that time intervals (between events) and space intervals (between two points of a rigid body) are values independent on the condition of motion of the reference body[xli]. Even though this sits nicely with our everyday intuitions of space and time, it leads to the problematic theorem of the addition of velocities which clashes with the principle of constancy of the velocity of light in vacuum. So, Einstein sought to point out what was wrong in the everyday intuitions, for it was these intuitions *anchored in the unconscious*[xlii] that led to the problematic situation in physics. In our everyday lives we take for granted the absoluteness of the notion of simultaneity – for it seems to us that the notion of two events happening at the same time cannot be treated as relative to motion[xliii]. Lorentz used the 'local time' coordinate, but it was treated as mathematical tool measuring the apparent time for the observer, as opposed to real, physical time. Einstein, on the other hand, approached the issue in a braver way, as he deduced the relativity of simultaneity and relativity of time and distance from the axioms by the use of simple thought experiments[xliv]. Simply put – if velocity of light in vacuum is constant, and should be constant for all reference systems, then a thought experiment in which we combine the two postulates points out that the values for time and space coordinates vary. Moreover, they vary in accordance with the equations of Lorentz Transformations (which Einstein deduces from simple geometry[xlv], without hypothesizing aether). This explains time dilatation and length contraction, while reducing number of independent hypothesis needed[xlvi]. The equations of Galilean transformations can be deduced from these if the velocities are sufficiently small when compared to the velocity of light[xlvii]. Special theory of relativity leaves us with a pseudo-Euclidean Minkowski's four-dimensional space, 'world' in which each event is described by three space-coordinates *x, y, z* and time coordinate *t*[xlviii]. What we gain is special principle of relativity for the phenomena in which *the laws, according to which the states of physical systems change, are independent of whether they are referred to one or the other of two systems of coordinates in uniform translatory motion relative to each other*[xlix]. The two branches of physics were re-united.

Yet, Einstein strived for even more – for, why should specific reference systems in specific type of motion be privileged? Privilege granted to inertial systems, leads to treatment of the space-time continuum as *absolutum,* as something physically real, as *independent in its physical properties, having a physical effect, but not itself influenced by physical conditions*[l]. It was in the general theory of relativity that the requirement of relativity gains true universality –

and the equations depicting natural laws are to hold for all systems regardless of their state of motion. Impetus to Einstein thinking was the *realization that all the natural laws except the law of gravity could be discussed within the framework of the special theory of relativity*[li]. The theory needed to be revised to account for that phenomenon as well. As special theory of relativity robs us of the concept of time we're so immersed in, in our everyday life, general theory of relativity does away completely with the notion of space that we're used to. We tend to think of space as something that would still remain, even if all matter from it miraculously disappeared, as though space is some excessively big box that exists independently of matter it contains. The notion of inertial system in classical mechanics was also based on this *mysterious property of physical space*[lii], as inertia *resists acceleration relative to space*[liii]. Einstein, working of Galilean (weak) equivalence principle of the equality of inertial mass and gravitational mass[liv], concludes that the two measures must refer to the same phenomena; same quality is manifested in inertia and weight. In this conclusion, we see once again an aspiration for logical paucity in completeness of representation of phenomena of nature realized, for why should we have two completely differently defined measures to refer to something that manifests itself as always numerically equal. In Einstein's own words *the possibility of explaining the numerical equality of inertia and gravitation by the unity of their nature gives to the general theory of relativity, according to my conviction, such superiority over the conceptions of classical mechanics, that all difficulties encountered in its development must be considered as small in comparison with this progress*[lv]. Before examining the difficulties, resolution of which took Einstein eight years, one needs to recognize the sheer beauty in the logical paucity accomplished by general theory of relativity. To only name a few accomplishments - it (i) eliminates the circular argument for the principle of inertia and (ii) attribution of properties to space, by (iii) eliminating the privileged 'inertial systems' and still leaves Minkowski metric for the space-time continuum of special relativity valid for all sufficiently small finite regions of space-time, providing the absence of gravitational field.

That brings forth the difficulties, and the difficulties encountered were immense since the vocabulary of Euclidean geometry can't be applied in the accelerated reference frame[lvi], and – as noted in the equivalence principle – gravitational field is equivalent to acceleration of the reference frame. In the search for appropriate' language', Einstein found that Gauss surface coordinates and Riemann's theory offer a solution for the geometric representation of space i.e. *that the appropriate substitute* for Euclidean vocabulary *is the group of all continuous (analytical) transformations of the coordinates*[lvii]. Sufficiently small finite regions of such a representation are describable in Euclidean vocabulary[lviii], which accounts for applicability of specific theory of relativity to the phenomena, yet it provides us with mathematical apparatus to describe phenomena previously indescribable. In this language, space cannot be dissociated from physical content. With widening of the reference frame – rigid reference bodies are replaced by reference mollusks, none of which is privileged for description of natural laws[lix]. Space time behavior of the gravitational field can be derived from specific Galilean cases by transformations of the coordinates. In simplest possible terms, as opposed to the 'flat' space-time regions in which gravity is weak, in a new mathematical language presence of the gravitational field would be defined as curvature in the space-time (space-time distortion). In a bit more complex language –building off of divergence-less tensor character of the density of matter (energy) presentation in the limited Galilean cases (where energy and momentum are preserved, i.e. of the tensor character), in the language of expressing the latter case continuity equation should incorporate covariant derivative[lx]. Long and complex story short, we are left with a quasi-spherical geometric representation of universe as a closed system[lxi] marked by an ongoing dance of mass/energy and space time. While this seems as remote as one can get from our everyday representation of phenomena, experience seems to concord – all experimental results still seem to concord to Einstein's field equations. This seems to be in accord with what Einstein wanted from a theoretical construction. As was noted before these brief dealings[lxii] with the specifics of his ideas in physics, the theoretical construction of physics should depart from the primary concepts applied to the Experienced, while it gains validity solely through its serviceability in providing order to the domain of Experience. This is not to say that Einstein thought that the general theory of relativity met all of the requirements he posits to the construction in theoretical physics. It diverges from his ideal, as Einstein himself reports[lxiii], in two significant aspects, namely (i) the requirement for the completeness in the representation of the phenomena is not met as an explanation of the atomistic structure of matter was missing; and (ii) logical paucity is questionable, since the field still seemed to be marked with two logically unconnected parts – electromagnetic and gravitational. It was the first of these deficiencies that gave rise to a completely new theoretical approach in physics, quantum theory, and once again – duality in physics reemerged.

Einstein was troubled by the probabilistic nature of the quantum theory responsible for the new duality in physics, even though he noted that such a theoretical construction does do justice to the experienced concerning the atomistic structure of matter. He was reluctant to accept that we can account for the phenomena of Nature solely through the language of a game of chance. In Kantian terms, he believed in the comprehensibility of the world. For him the physicist is *a man engaged in solving a well-designed word puzzle. He may, it is true, propose any word as the solution; but, there is only one word which really solves the puzzle in all its parts. It is a matter of faith that nature–as she is perceptible to our five senses–takes the character of such a well formulated puzzle*[lxiv]. Einstein's theory of relativity, deficiencies included, possesses a specific beauty that must appeal to any philosopher, for embedded in it is the real appreciation of the philosophical question. In a sense, it arose out of epistemological ponderings, and throughout its elaboration epistemological awareness is present, as Einstein is careful not to overstep the boundary the skeptic posits. He writes[lxv]: *Hume saw that concepts which we must regard as essential, such as, for example, causal connection, cannot be gained from material given to us by the senses. This insight led him to a sceptical attitude as concerns knowledge of any kind. If one reads Hume's books, one is amazed that many and sometimes even highly esteemed philosophers after him have been able to write so much obscure stuff and even find grateful readers for it.* Einstein's appreciation of Kant's transcendental approach has already been noted in the earlier sections. Einstein's theory does not arise out of experience and at no point itself professes to be a statement about the external world. It is a construction of the physicists mind, not stranded on the *metaphysical by-way*[lxvi] and at the same time accomplishes to account for the vast number of phenomena while preserving the logical simplicity.

This is not to say that Einstein himself, especially in his later writings, is void of metaphysical reflection. If anything, he criticizes empiricist of his time for exhibiting too much of 'metaphysical fear'[lxvii]. Of Nature he writes: *Our experience up to date justifies us in feeling sure that in Nature is actualized the ideal of mathematical simplicity. It is my conviction that pure mathematical construction enables us to discover the concepts and the laws connecting them which give us the key to the understanding of the phenomena of Nature. (...)In a certain sense, therefore, I hold it to be true that pure thought is competent to comprehend the real, as the ancients dreamed*[lxviii]**.**

While these thoughts emerge in Einstein's later writings, and reflect his dissatisfaction with the probability equations in physics, it needs to be noted that it is not in contradiction with the epistemological awareness applied in the elaboration of the theory of relativity. One can see, though, how this might trouble a systematic epistemologist. Einstein devotes following passage to the dealings of epistemologist with a theoretical physicist: *He therefore must appear to the systematic epistemologist as a type of unscrupulous opportunist: he appears as realist insofar as he seeks to describe a world* *independent of the acts of perception; as idealist insofar as he looks upon the concepts and theories as the free inventions of the human spirit (not logically derivable from what is empirically given); as positivist insofar as he considers his concepts and theories justified only to the extent to which they furnish a logical representation of relations among sensory experiences. He may even appear as Platonist or Pythagorean insofar as he considers the viewpoint of logical simplicity as an indispensable and effective tool of his research.*[lxix]

And indeed, as is noted throughout the preceding pages, in the vast philosophical literature dealing with Einstein's theory – he is designated in many ways, as a metaphysical realist, positivist, idealist; his theory portrayed as an instance of Platonic panmathematicism, neo-Kantianism of Cassirer's kind, conventionalism or as an affirmation of one or several of the philosophical approaches. In light of Einstein's words in the preceding passage, this paper refrains from name-calling, yet seeks to point out that even in his thought on Nature he is not guilty of the 'metaphysical sin'.
Namely, if one produces a logical-mathematical system to provide order to the phenomena of Nature, somewhere in the background, lurking, so to speak, is the idea that such an order can be found among the totality of the Experienced. Einstein himself, in light of his appreciation of Kant, treats his theory as a question proposed to the phenomena of Nature[lxx] . Nature (i.e. as it is experienced) is to reply by concurring or not to the logical construction at hand. But if there is no faith that it might, why would one come up with such a question? Truths proclaimed in his theory emerge solely in relations existing in the logical construction. Reality, in our everyday dealing and physics alike, is the logical construction. This is to say nothing of the proverbial search for truth of the external world. To seek the truth, for Einstein, seems to be synonymous to the search for the appropriate question. As far as attaining it goes, even if it was beyond our grasp, he seemed to think that the quest itself was precious[lxxi]. Is the proverbial philosophical skeptic to be silenced by Einstein's theory?

The Greek word σκεπτικοι denotes those who are still searching. In this, original sense of the word, Einstein was a σκεπτικοσ to the very end. This is not to provide him with yet another philosophical title, this is solely to say that his stance is marked with a specific kind of openness to the possibility that, to extend the metaphor he uses, the word he suggests might or might not solve the puzzle, combined with the thought that the puzzle might or might not prove to be solvable in the first place. The latter for him, not unlike Kant, is a matter of faith. This openness to doubt consistently re-emerges in his work as a building block for the next set of questions to be posed to the Experienced. When he proposed the general theory of relativity, special theory of relativity and its axioms were reduced to specific cases. In the structure of general relativity the speed of light is no longer constant, privileged inertial systems are eliminated. If the word does not fit to solve the puzzle in all its parts, and yet just feels 'right', there are two possible courses of action. One can dogmatically cling to the word and seek to explain the deficiency of the remainder of the puzzle, or one can question the proposed word. The second option is the only option leaving open the dialectics of thought. Remove doubt from the equation, and what you have is a standstill of thought. Thus, instead of taking his approach to be unscrupulously opportunistic with regard to epistemology, contemporary epistemologists should take note of what happens when one takes skepticism seriously. As for the mentioned duality in physics, it still exists. Through the course of time, both quantum physics and general theory of relativity gain more and more 'serviceability points' in the domain of Experience. Although efforts have been made, it seems that we still await someone to propose the right word, to pose the right question. And consequentially, open new ones.

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Abbreviations

AVTP Planck, M. 1915. *Eight Lectures on Theoretical Physics.* New York: Columbia University Press.

CFTP Einstein, A. 1940. ″Considerations Concerning the Fundaments of Theoretical Physics.″ *Science 91,* no. 2369: 487-492.

G Einstein, A. 1950. ″On the Generalized Theory of Gravitation.″ *Scientific American 182,* no. 4: 14-17.

HIC Einstein, A. 1982. ″How I Created the Theory of Relativity.″ *Physics Today:* 45-47.

KRV Kant, I. 1919 . *Kritik der reinen Vernunft.* Leipzig: Verlag von Felix Meiner.

LLP1 Einstein, A. 1944. ″Remarks on Bertrand Russell's Theory of Knowledge.″ *The Philosophy of Bertrand Russell: The Library of Living Philosophers V*, ed. Paul Arthur Schilpp, 277-293. Chicago: Open Court Publishing.

LLP2 Schilpp,, Paul A., ed. *Albert Einstein: Philosopher Scientist: The Library of Living Philosophers VII.* Chicago: Open Court Publishing , 1949.

MR Einstein, A. 2008. *The Meaning of Relativity.* London: Routledge.

OMTP Einstein, A. 1934. ″On the Method of Theoretical Physics. ″*Philosophy of Science 1*, no. 2: 163-169

PR Einstein, A. 2003. ″Physics and Reality.″ *Daedalus*: 22-25.

R Einstein, A. 1920. *Relativity: The Special and The General Theory.* 3d ed.London: Methuen & Co.

T Hume, D. (1739/1965). *A Treatise of Human Nature.* Oxford: Clarendon Press.

ZER Cassirer, E. 1953. *Substance and Function and Einstein's Theory of Relativity*. Chicago: Dover Publishing Inc

[i] Russell , B. 1925. *ABC of Relativity*. London: George Allen & Unwin Ltd.
[ii] Hentschel, K. 1990. ″Philosophical Interpretations of Relativity Theory: 1910-1930.″ *Proceedings of the Biennial Meeting of the Philosophy of Science Association, 1990* 2: 169-179. It needs to be noted at this point that some of this charges, i.e. claims philosophical lines of thought posit on Einstein's work will be dealt with in this paper as well. For the purpose of clarity, though, most of the referrals will appear in the footnotes.
[iii] Reprinted as Einstein, A. 1934. ″On the Method of Theoretical Physics.″ *Philosophy of Science* 1, no. 2: 163-169. In future references cited as OMTP.
[iv] Cassirer, E. 1921. *Zür Einsteinschen Relativitätstheorie.* Berlin: Bruno Cassirer Verlag. For the purpose of this paper English translation was used from Cassirer, E. 1953. *Substance and Function and Einstein's Theory of Relativity*. Chicago: Dover Publishing Inc.; In the following text cited as ZER. For the listed citation see p. 358.
[v] Max Planck offers an insightful portrayal of the development of physics, starting with these branches in his *Acht Vorlesungen über theoretische Physik*, delivered in 1909. For the purpose of this paper English translation was used in Planck, M. 1915. *Eight Lectures on Theoretical Physics.* New York: Columbia University Press. In the following text cited as AVTP.
[vi] OMTP, 166.
[vii] Hume, D. 1965. *A Treatise of Human Nature.* Oxford: Clarendon Press. For his citation see p. 87. In future references cited as T.
[viii] Hume, for example, concludes from possibility of error in large mathematical computations to the error in simpler mathematical forms (T, 181). This is by no means conclusive argument, but totality of his argumentation is compelling.
[ix] For further elaboration see T, 183-
[x] It need not be stated, as it is a piece of common knowledge among those who are students of philosophy that understanding Hume's approach requires understanding of the previous skeptical approaches in philosophy, Academic skepticism, Pyrrhonists, Descartes, etc. While not everybody would agree that Hume's approach was fully skeptical, or that we should categorize him as a skeptic at all, there is no space to enter into such a discussion here.
[xi] Kant, I. 1919 . *Kritik der reinen Vernunft.* Leipzig: Verlag von Felix Meiner. For the citation XIII 11-29, p. 26. (In the following text cited as KRV) English translation from Kant, I. 1881. *Critique of Pure Reason.* London: Macmillan and co., p. 368: *They comprehended that reason has insight into that only, which she herself produces on her own plan, and that she must move forward with the principles of her judgments, according to fixed law, and compel nature to answer her questions, but not let herself be led by nature, as it were in leading strings, because otherwise, accidental observations, made on no previously fixed plan, will never converge towards a necessary law, which is the only thing that reason seeks and requires. Reason, holding in one hand its principles, according to which concordant phenomena alone can be admitted as laws of nature, and in the other hand the experiment, which it has devised according to those principles, must approach nature, in order to be taught by it: but not in the character of a pupil, who agrees to everything the master likes, but as an appointed judge, who compels the witnesses to answer the questions which he himself proposes.*
[xii] OMTP, 167; Here, and in the following passages it shall become clear why Einstein's work tends to be associated with Kantian tradition. While he himself frequently mentions Kant's philosophy as a source of particular lines of thought that led him in his work, one shall see that his own ideas overstep, so to speak, this philosopher's elaboration of the faculty of Reason.
[xiii] ZER, 364
[xiv] Ibid. 364 - Cassirer at this point of analysis portrays this on the analysis of the concept of inertia since Neumann. Inertia appears, not as an absolute and inherent property of things and of bodies, but as the free establishment of a certain standard and symbol of measurement, by virtue of which we can hope to reach a systematic conception of the laws of motion. In this alone is rooted its reality, i.e., its objective and physical significance.
[xv] OMTP, 164
[xvi] Einstein, A. 1944. ″Remarks on Bertrand Russell's Theory of Knowledge.″ *The Philosophy of Bertrand Russell: The Library of Living Philosophers V*, ed. Paul Arthur Schilpp, 277-293. Chicago: Open Court Publishing. In the following text cited as LLP1. For this citation see p.285

[xvii] The final blow was delivered by the general theory of relativity, and this is elaborated in the following passages. But here it needs to be noted that theory of relativity with its postulates provides this blow in quite a unique way. Awareness of the applicability of Newtonian physics and Euclidean geometry in a limited field of experience (as these are applied in the special theory of relativity) is incorporated in the theory, they do not have the fate of *elan viate* and similar theoretical constructions in the study of nature that wound up completely deleted from the domain of science. If one wants to limit his questions on the phenomena of Nature, his questions can still be posed in the vocabulary of these physical and mathematical constructions.

[xviii] Einstein, A. 2003. ″Physics and Reality.″ *Daedalus*: 22-25. For the citation refer to p. 24. Originally published in 1936. In future references cited as PR.

[xix] This is to say nothing of Kant's notions of space and time as the conclusions from transcendental aesthetics seem to fit with the description of space and time in the theory of relativity. While some would argue that, since Kant's notion of space and time arose out of Newtonian physics, this means they are somehow in conflict with the theory of relativity, I believe that the exposition in this paper should point out that, if anything, Einstein's treatment of space and time is made possible by the revision these notions get in the transcendental aesthetics. It is there that these ideas are treated as preconditions of sensibility and not as something which belongs as a property to things. (see KRV, 75-105)

[xx] Einstein, A. 1949. ″Autobiographical Notes.″ *Albert Einstein: Philosopher Scientist: The Library of Living Philosophers VII,* ed. Paul Arthur Schilpp. This citation on p. 13; In the following text Schilpp is cited as LLP2. Those seeking to point out that Einstein was a conventionalist in the philosophical sense frequently use this passage, along with the lines from *Vier Vorlesungen über Relativitätstheorie* , first published in 1922, where he writes about the possibility of the comparison of experiences of individuals due to the existence of language. In that piece of writing we find Einstein criticizing specific philosophers for removing concepts into the *intangible a priori* thus completely separating them from the 'given' in Experience. But, as the following passages of this paper should show, one should not to be quick to assign any philosophical designation to Einstein that easily. What one should read into these passages is Einstein's awareness of the perils lurking in the form of the charge for solipsism, again a note on his awareness of epistemological issues. For the aforementioned passages refer to Einstein, A. 2008. *The Meaning of Relativity.* London: Routledge. specifically, p. 2. In the following text cited as MR.

[xxi] PR, 24; the applicability in Experience Einstein stresses has led many to call him, or claim him, for the philosophical 'domain' of positivism. Most of the charges for positivism tend to be accompanied with passages from his elaboration of relativity of simultaneity which should be explicated in the following passages. Namely, when Einstein seeks to explain aforementioned relativity he points out that we cling to the idea of absolute simultaneity even though this cannot be verified in experience – the choice of different reference frames influences whether or not two specific events will be designated as simultaneous. The following passages of this paper should show how Einstein's approach diverges from the stances of positivists in philosophy.

[xxii] PR, 24

[xxiii] i.e. the aforementioned serviceability must not be disregarded. The theoretical construction has value only if it provides order to the Experienced.

[xxiv] As Max Planck puts it in AVTP (see foot note 5 of this paper): *the result for the sake of whose achievement are sacrificed the directness and succinctness such as only the special sense perceptions vouchsafe to physical ideas (...)is nothing more than the attainment of unity and compactness in our system of theoretical physics, and, in fact, the unity of the system, not only in relation to all of its details, but also in relation to physicists of all places, all times, all peoples, all cultures.* (...) *Certainly, the system of theoretical physics should be adequate, not only for the inhabitants of this earth, but also for the inhabitants of other heavenly bodies.* For the citation refer to p. 7

[xxv] E.g.PR, 25

[xxvi] AVTP, 120

[xxvii] i.e. special principle of relativity

[xxviii] ZER, 368-369

[xxix] E.g. Einstein, A. 1920. *Relativity: The Special and the General Theory.* 3d ed. London: Methuen & Co. This citation on p. 17. In the following text cited as R.
[xxx] Designating the speed of light in vacuum (*c*) as a physical constant with value of 300 000 km/s (more precisely 299,792,458 m/s); Maxwell's equations published in 1861 and 1862 and Michelson- Morley experiment in 1887 led to the agreement in the field of electrodynamics that the speed of light does not vary in relation to movement of the emitting body or the movement of the observer.
[xxxi] For a more elaborate explanation of the resolution of this apparent contradiction see R, 17-48; MR, 25-56.
[xxxii] $x' = x - vt \quad y' = y \quad z' = z$
[xxxiii] First published in a paper *Zur Elektrodynamik bewegter Körper* in1905.
[xxxiv] For those skilled in the language of physics this might seem as an oversimplified portrayal, while those lacking the knowledge of the basics might seek more detail even for this abbreviated version. Since this type of portrayal fits the purpose of this paper, additional references are added to address both aspects of this deficiency due to brevity.
[xxxv] Three important variables in his experiment were the speed of light relative to the liquid, speed of light relative to the tube and speed of liquid relative to the tube. For a simple elaboration of this experiment for non-physicist, see Einstein's portrayal in R, 39-41, or Planck's in AVTP, 112-.
[xxxvi] Michelson-Morley experiment was supposed to repeat the Fizeau's results but in respect to matter. It was presumed that if two mirrors are placed on a rigid body , with reflecting sides facing each other, time *T* needed for a ray of light to pass from one mirror to the other when the body is at rest (relative to aether) would be different from time *T′* measured when the rigid body is in motion. It happened though, that the results expected by mathematical calculations were not obtained, making this experiment probably the most renowned failed experiment ever. (For a more detailed account of the failure see R, 57- 58.)
[xxxvii] Lorentz reached the conclusion in 1895 as G. FitzGerald did in 1889.
[xxxviii] For Lorentz this was just a heuristic tool, a 'local time coordinate', the real physical time was still the one from classical mechanics. (It needs to be noted that in limited space of this paper, more complex issues are left unaccounted for. For a more detailed account of the relevant issues in physics at that time, including the instability of Lorentz electron and Planck radiation law, which led Einstein to question the possibility of the exclusive electromagnetic or mechanical worldview, see Miller, A. I. 1982. ″On Einstein's Invention of Special Relativity.″ *Proceedings of the Biennial Meeting of the Philosophy of Science Association 1982 2*: 377-402. Specifically on Lorentz p. 382).
[xxxix] For a more detailed elaboration of how this served as an impetus for Einstein see additionally Einstein, A. 1940. ″Considerations Concerning the Fundaments of Theoretical Physics.″ *Science 91,* no. 2369: 487-492. (In the following text cited as CFTP.) For a simpler elaboration by Einstein himself see a translation of a lecture delivered in Kyoto on 14 December 1922 published as Einstein, A. 1982. ″How I Created the Theory of Relativity.″ *Physics Today*: 45-47. (In the following text cited as HIC.)
[xl] More precisely, Lorentz's theory removes the inconsistency in favor of electromagnetic theory, but further developments pointed out the language of classical mechanics (specifically principle of special relativity) was still needed for explanation of specific phenomena in the field of electrodynamics as well.
[xli] A simple elaboration in R, 30.
[xlii] See his remark in LLP2, 53.
[xliii] See footnote 21.
[xliv] It needs to be pointed out that his use of thought experiments as a tool for this deduction further elucidates his awareness of the philosophical issues and approaches of his time.
[xlv] See R, 115-129.
[xlvi] It also precludes Lorentz hypothesis on the nature of electron s from physics, see R, 51.
[xlvii] I.e. classical mechanics need a correction solely for the higher speed (R, 33; ZER, 372). Additional important consequence (especially later on in the development of the general theory) was the principle of equation of mass and energy (R, 45-47;CFTP, 490).

[xlviii] R, 55-57.
[xlix] ZER, 372
[l] MR, 58
[li] HIC, 47
[lii] CFTP, 490
[liii] See Einstein, A. 1950. ″On the Generalized Theory of Gravitation.″ *Scientific American 182,* no: 4: 14-17. For this particular citation refer to p. 15. In the following text cited as G.
[liv] R, 65; CFTP, 490
[lv] MR, 60
[lvi] HIC, 47
[lvii] G, 15
[lviii] i.e. in the Euclidean vocabulary as applied in Minkowski's metric, with the inclusion of time coordinate.
[lix] Thus the true generalization of the principle of relativity would be – that any mollusk chosen as a reference body is equally valid for the formulation of natural laws (see R, 99).
[lx] Each stage of Einstein's development of General Theory of Relativity leads to higher degree of abstraction, and consequentially – a more complex mathematical representation.
[lxi] HIC, p.47
[lxii] Although it is clear that such a brief portrayal could hardly profess to cover all significant aspects of the theory of relativity, the brief portrayal serves as a sufficient indicator of the implications of his awareness of epistemological issues for his achievements in the study of Nature.
[lxiii] See e.g. G, 490
[lxiv] PR, 25
[lxv] LLP1, 285
[lxvi] ZER, 359
[lxvii] LLP1, 289
[lxviii] OMTP, 167; this passage tends to be stressed by those who claim that Einstein should be read as an advocate of panmathematicism.
[lxix] LLP2, 684
[lxx] G, 17
[lxxi] CFTP, 492