EINSTEIN: PHILOSOPHICAL IDEAS

The most obvious philosophical impact of Einstein's scientific work is that it took a number of fundamental questions that had been considered to be almost exclusively philosophical (indeed metaphysical for many), and moved them into the domain of science – at the same time giving answers to these questions which completely changed the way we looked at them. This is the popular view of Einstein's work, and it is largely accurate. However it is not the view of many professional philosophers (few of whom understand science - unlike many of their illustrious predecessors). An unfortunate consequence of this (and of the later failure of philosophy to seriously address the questions raised by quantum mechanics) is that philosophy has really been left behind by modern physics.

Einstein's philosophical ideas were wide-ranging, and often very original. This has made them hard for philosophers to categorize, since they sometimes had little connection with mainstream philosophical themes, before or since. Indeed, in the form presented by Einstein, they completely redrew important portions of the philosophical map. Some philosophers tend to feel that such redrafting is their exclusive prerogative, and indeed most scientists have been quite content to let philosophers decide the terms and rules of philosophical discussion, and how the important questions should be framed. Accordingly, Einstein has often been accused by professional philosophers of being a kind of philosophical dilettante, sometimes doing little more than cherry-picking from different philosophical doctrines. In a famous passage, Einstein addressed this point:

"*The reciprocal relationship of epistemology and science is of a noteworthy kind. They are dependent upon each other. Epistemology without contact with science becomes an empty scheme. Science without epistemology is – insofar as it is thinkable at all - primitive and muddled. However, no sooner has the epistemologist, who is seeking a clear system, fought his way through to such a system, than he is inclined to interpret the thought-content of science in the sense of his system and to reject whatever does not fit into his system. The scientist, however, cannot afford to carry his striving for epistemological systematics that far. He accepts gratefully the epistemological conceptual analysis; but the external conditions, which are set for him by the facts of experience, do not permit him to let himself be too much restricted in the construction of his conceptual world by the adherence to an epistemological system. 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.*"

Einstein, in Schilpp, LLP, "reply to criticisms", p. 683

One cannot fail to notice the humour here, at the expense of professional philosophers – Einstein was in the habit of teasing. However, these remarks have often been misunderstood or ignored. His views, on various occasions, have been said to combine logical positivism, conventionalism, idealism, logical empiricism, realism, and neo-Kantianism, to name a few. This kind of categorization, of what is in fact a strikingly original complex of ideas, may conveniently serve the interests of the many philosophical factions active since Einstein's work. But it does so at the cost of burying his ideas under a mountain of 'isms', which ultimately gives little understanding of these ideas. It is not so much that the details are wrongly understood (although they often are), but that there is no comprehension that the entire worldview being advocated by Einstein cannot be categorized in these ways – that he is proposing a different (sometimes radically different) doctrine, which has to be understood in its own right, and which often does not conform to many of the usual guidelines of philosophical discussion.

This is not to say that Einstein's thinking does not take account of the works of philosophers before him. Indeed, he spent some time thinking about these when he was young, and later on, both in his correspondence and in his more philosophical writings, he devoted some attention to the work of Hume, Kant and the logical positivists. Much has been made of his occasional discussions with professional philosophers at this time. However it is important to realize that, while Einstein certainly saw himself as occasionally locked in debate with philosophical figures like Hume or Kant, this was, for him, entirely secondary to the very different kind of debate he was carrying on with Nature itself. In this debate, figures like Hume or Newton, just as much as his friends Besso, Solovine, and Hablich, or colleagues like Born and Bohr, were foils to the development of his ideas. But they were no more than this - ultimately, it seems that Einstein saw the ultimate debate as proceeding between himself and what he called 'the Old One', ie., whatever or whoever it was that was responsible for the incomprehensible order existing in the universe, and for the puzzles he was trying to solve. And for this debate, Einstein saw himself as using whatever tools seemed to him to be appropriate, provided they gave him access to what he undoubtedly saw, at least on some occasions, as the untainted, naked Truth.

Moreover, in this endeavour, Einstein felt quite clearly that the questions here were too important to be just left to the philosophers. They had certainly done an important job in clarifying ideas, but Einstein felt that they were simply not up to the task of answering the questions that both he and they were addressing:

It has often been said, and certainly not without justification, that the man of science is a poor philosopher. Why then should it not be the right thing for the physicist to let the philosopher do the philosophizing? Such might indeed be the right thing at a time when the physicist believes he has at his disposal a rigid system of fundamental concepts and fundamental laws which are so well established that waves of doubt can not reach them; but, it can not be right at a time when the very foundations of physics itself have become problematic as they are now. At a time like the present, when experience forces us to seek a newer and more solid foundation, the physicist cannot simply surrender to the philosopher the critical contemplation of the theoretical foundations; for, he himself knows best, and feels more surely where the shoe pinches. In looking for a new foundation, he must try to make clear in his own mind just how far the concepts which he uses are justified, and are necessities.

from "Physics and Reality" by Albert Einstein, J. Franklin Inst. **221**, 349-382 (1936)

In what follows we look at what he said on science and scientific method, and on a large variety of epistemological problems, as well as his views on metaphysics and its relationship with scientific practise.

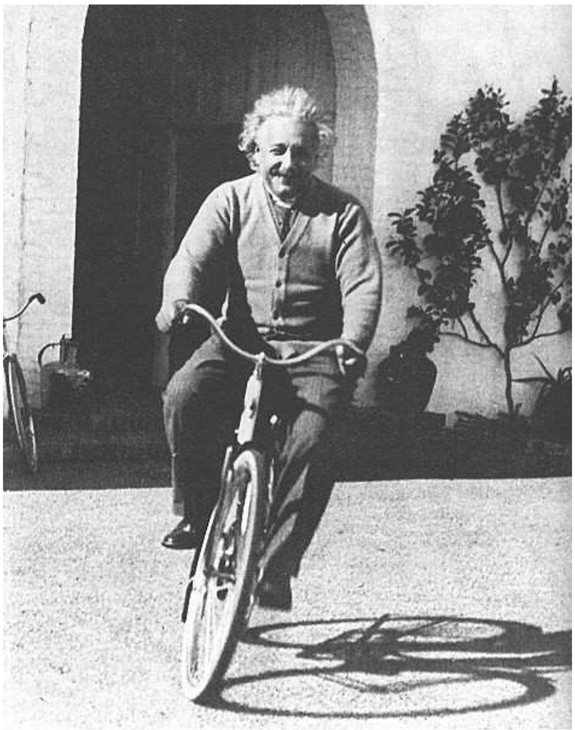

FIG. 1: Einstein in California in 1931. At this time he was considering where to live, having already decided to leave Germany. In California he was entertained by Millikan, Hubble, and Baade, whose experimental and observational work had helped confirm Special and General Relativity. Einstein's philosophical views had by this time reached their mature stage, discussed herein.

Most of his opinions on these topics are well known. However he also tied them together with some very interesting introspections on the nature of thinking itself. We begin with these ideas, which are often ignored in discussions of Einstein's ideas, together with his views on a number of other topics (notably on the relationship between belief and reason); they form something of a seamless whole, and it is a mistake to try and divide them.

NOTE: It is important to realize, when looking at what Einstein said, that many of the remarks and views attributed to him are complete fabrications. Indeed it has been estimated that over 90% of all quotes attributed to Einstein, in print and on the web, were not his. In the 20th century, perhaps only Gandhi, Lenin, and Mao Tse-Dung have been traduced to such an extent. One needs to be particularly careful of religious and political opinions attributed to Einstein. Some of these quotes are obviously false - either because of the style they are written in, or because the views expressed therein are so obviously at variance with what Einstein said in his books. Others are less obviously fabricated. Luckily we have easy access both to his own writings (which are still all in print, and often reproduced on internet sources) and to the indexed Einstein archives, which are very complete and can be found on line. If in doubt, one should refer to these. The "Library of Living Philosophers" volume on Einstein contains a fairly comprehensive listing of Einstein's published work, his radio interviews, and newspaper articles.

1. METAPHYSICAL IDEAS

Einstein was very clear that the quest to understand Nature could not be simply confined to the traditional objects of inquiry in the Natural Sciences - that indeed, one had to engage in what most people would think of as purely philosophical inquiry. Just what he meant by philosophical inquiry, and what were the themes that he himself considered to be interesting, we will see later. But his ideas began right where those of much traditional philosophy begin, in the analysis of our own thinking.

1.1. THOUGHT and LANGUAGE.

For Einstein, the kind of thinking that one employed in scientific research was of a specialized and particular kind, that had been developed over a long period of time; and he certainly saw himself as contributing to this evolution of the methodology. However, he also knew that this was just one kind of thinking, and that our thinking processes were quite generally rather limited by our own human limitations. He thus found it interesting to think about how thinking in general worked - indeed he found it to be a necessary part of scientific enquiry:

The whole of science is nothing more than a refinement of everyday thinking. It is for this reason that the critical thinking of the physicist cannot possibly be restricted to the examination of the concepts of his own specific field. He cannot proceed without considering critically a much more difficult problem, the problem of analyzing the nature of everyday thinking.

from: A Einstein, J. Franklin Inst. **221**, 349-382 (1936)

It would be hard for most professional philosophers to find fault with this last remark, as it is written. But two cautionary remarks are in order here. First, as we discuss more below, 'everyday thinking' was *not*, for Einstein, synonymous with everyday language; and second, the question, of how to understand human thinking and its limitations, was for him as much psychological as philosophical. Indeed, he clearly saw that much of our thinking proceeded at a level of which we were hardly aware. One of the most fascinating discussions by Einstein of his own thinking appeared in his answers to a questionnaire from the mathematician J Hadamard, who was investigating the thought processes involved in scientific work. Consider the following:

QUESTION: It would be very helpful for the purpose of psychological investigation to know what kind of internal or mental images, what kind of 'internal words', mathematicians make use of; whether they are motor, auditory, visual, or mixed, depending on the subject which they are studying.

Especially in research thinking, do the mental pictures or internal words present themselves in the full consciousness or the fringe consciousness...?

ANSWER: My dear colleague

In the following, I am trying to answer in brief your questions as well as I am able. I am not satisfied myself with those answers, and I am willing to answer more questions if you believe this could be of any advantage for the very interesting and difficult work you have undertaken.

(A) The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychic entities which seem to serve as elements in thought are certain signs and more or less clear images which can be 'voluntarily' reproduced and combined.

There is of course, a certain connection between those elements and relevant logical concepts. It is also clear that the desire to arrive finally at logically connected concepts is the emotional basis of this rather vague play with the above-mentioned elements. But, taken from a psychological viewpoint, this combinatory play seems to be the essential feature in productive thought - before there is any connection with logical construction in words or other kinds of signs which can be communicated to others.

(B) The above-mentioned elements are, in my case, of visual and some of muscular type. Conventional words or other signs have to be sought for laboriously only in a secondary stage, when the above-mentioned associative play is

sufficiently established and can be reproduced at will.

(C) According to what has been said, the play with the above-mentioned elements is aimed to be analogous to certain logical connections one is searching for.

(D) Visual and Motor: In a stage where words intervene at all, they are, in my case, purely auditive, but they interfere only in a secondary stage, as already mentioned.

(E) It seems to me that what you call full consciousness is a limiting case that can never be fully accomplished. This seems to me connected with the fact called the 'narrowness of consciousness' (Enge des Bewusstseins).

Remark: *Prof. Max Wertheimer has tried to investigate the distinction between mere associating or combining of reproducible elements, and between understanding* (organisches Begreifen). *I cannot judge how far his psychological analysis catches the point.*

Extract from "*An essay on the psychology of invention in the mathematical field*",
by Jacques Hadamard (Princeton Univ Press, 1945)

What is startling to many readers here is the clear recognition, by Einstein, of the really quite primitive nature of our thinking, and of the vast mysteries lying, not just out there in the universe, but in the deeper workings of our own minds. As we discuss below, this led him, as it had Hume and Kant before him, to a discussion of the limitations, to human thought, that were inherent in our very nature. But Einstein saw very clearly that this discussion should not be applied solely to those thinking processes that could be formulated entirely in linguistic terms. In this his attitude was fundamentally different from that of 20th century Anglo-American philosophy (itself strongly influenced by ideas from Vienna); for him language was a higher-level faculty, which was not involved in our contact with, and understanding of, physical reality at the most basic level available to us. Thus while science undoubtedly needs the resources of ordinary language to proceed, it also needs to work on a deeper level. Einstein summarized his views on the higher-level thinking involved in language, and its relationship to scientific thinking, in the following:

The First Step towards language was to link acoustic or otherwise communicable signs to sense-impressions. Most likely all sociable animals have arrived at this primitive kind of communication – at least to a certain degree. A higher development is reached when further signs are introduced and understood which establish relations between those other signs designating sense-impressions. At this stage it is already possible to report somewhat complex series of impressions; we can say that language has come to existence. If language is to lead at all to understanding, there must be rules concerning the relations between the signs on the one hand and on the other hand there must be a stable correspondence between sings and impressions. In their childhood individuals connected by the same language grasp these rules and relations mainly by intuition. When man becomes conscious of the rules concerning the relations between sings the so-called grammar of language is established.

In an early stage the words may correspond directly to impressions. At a later stage this direct connection is lost insofar as some words convey relations to perceptions only if used in connection with other words (for instance such words as: "is", "or", "thing"). Then word-groups rather than single words refer to perceptions. When language becomes thus partially independent from the background of impressions a greater inner coherence is gained.

Only at this further development where frequent use is made of so-called abstract concepts, language becomes an instrument of reasoning in the true sense of the word. But it is also this development which turns language into a dangerous source of error and deception. Everything depends on the degree to which words and word-combinations correspond to the world of impressions.

What is it that brings about such an intimate connection between language and thinking? Is there no thinking without the use of language, namely in concepts and concept-combinations for which words need not necessarily come to mind? Has not everyone of us struggled for words although the connection between "things" was already clear?

We might be inclined to attribute to the act of thinking complete independence from language if the individual formed or were able to form his concepts without the verbal guidance of his environment. Yet most likely the mental shape of an individual, growing up under such conditions, would be very poor. Thus we may conclude that the mental development of the individual and his way of forming concepts depend to a high degree upon language. This makes us realize to what extent the same language means the same mentality. In this sense thinking and language are linked together.

What distinguishes the language of science from language as we ordinarily understand the word? How is it that scientific language is international? What science strives for is an utmost acuteness and clarity of concepts as regards their mutual relation and their correspondence to sensory data. As an illustration let us take the language of Euclidian geometry and algebra. They manipulate with a small number of independently introduced concepts; respectively symbols, such as the integral number, the straight line, the point, as well as with signs which designate the fundamental operations, that is the connections between those fundamental concepts. This is the basis for the construction, respectively, and definition of all other statements and concepts. The connection between concepts and *statements on the one hand and the sensory data on the other hand is established through acts of counting and measuring, whose performance is sufficiently well determined.*

from "The Common Language of Science", taken from
Albert Einstein "The Theory of Relativity and Other Essays" MJF Books New York, NY

Here we see many of the ingredients which Einstein felt were important to thinking in general, as well as to scientific thought. These include (i) the crucial role of our own perceptions and perceptual apparatus, in forming our experience, and the basic non-linguistic ideas that we and other animals have; (ii) the role of language and symbols in allowing us to formulate a more or less formal conceptual apparatus for analyzing our experience; and (iii) the very specific role of mathematics in allowing us to do this scientifically.

What is interesting from a philosophical point of view here is the extent to which Einstein was prepared to doubt, not just the evidence of our senses, but the sophistication and veracity of our own thinking. This raises an important question, which is hardly ever asked in Western philosophy. If our thinking is based on such primitive processes, then to what extent can we trust any of it at all? Thus, for example, it is almost universally accepted in the West that the entirely 'rational' or 'logical' part of our thinking cannot be doubted - that in fact it gives us '*a priori* truths'. But if these truths, as formulated, are fundamentally based the kind of crude psychophysical processes that Einstein describes, then why can we be so sure that they really do have the rock-solid stature that we give them? After all, they are just another set of conclusions that have been formulated in language, and apparently cannot be formulated without language (note that an appeal to modern mathematical logic will not help here - this is simply another language). Thus they are open to the same charge that Einstein levels at all language, viz., that it is a 'dangerous source of error and deception'.

As we will see, there seems little doubt that Einstein was at least to some extent aware of this question, as constituting a problem for any kind of rational inquiry. It should also be noted here that the ideas that Einstein expresses, of our basic thought processes as being fundamentally based in simple associations, have certainly been largely confirmed by modern neurology, which so far offers little evidence for anything in mental activity but a set of complex interacting physical processes. We certainly have a much more detailed picture of these neurological processes now, and there is a promise of revolutionary advances in the next few decades, in our understanding of the relationship between these processes and what we think of as conscious thought. But, as we have seen, conscious thought was for Einstein only a part of our thinking, not necessarily the most important. Indeed, it is clear from both his work and from his many remarks on his own thinking processes, that the subconscious side of his thinking (which was clearly a crucial part of his remarkable creative powers) was crucial to him. Indeed, this feature was part of what he regarded as not only psychologically important, but also philosophically fundamental, viz., what he called the 'free play of the mind' in all creative thinking, which allows us to get to the underlying reality beneath our primitive surface thinking, which itself is conducted only in terms of language and symbols.

We shall see this in more detail in what follows, and we will return to the idea of the 'free play of the mind', and of what kind of picture of the mind this might involve. But first we need to deal with another crucial feature of Einstein's philosophical views, which is also often ignored in discussions of this kind.

1.2. FAITH and REASON

It is not possible to understand Einstein's epistemological views without first reviewing what can only be described as his *spiritual* feelings, about the relationship existing between himself (and also other humans), and the universe as a whole. This was part of the very basis of his epistemology, of what he called his 'epistemological credo'. Since he made it clear that this credo constituted a faith, not demonstrable by reason, then we have to treat it as such, if we are to fully grasp his philosophical position.

A good description of his feelings on this topic was given by him in 1930, in a short article destined for an English-speaking audience; the following is a short extract from it:

"*The most beautiful thing we can experience is the mysterious. It is the fundamental emotion that stands at the cradle of true art and true science. Whoever does not know it and can no longer wonder, no longer marvel, is as good as dead, a snuffed-out candle. It was the experience of mystery – even if mixed with fear – that engendered religion. A knowledge of the existence of something we cannot penetrate, our perceptions of the profoundest reason and the most radiant beauty, which only in their most primitive forms are accessible to our minds – it is this knowledge and this emotion that constitute true religiosity; in this sense, and this alone, I a deeply religious man. I cannot conceive of a God who rewards and punishes his creatures, or has a will of the kind that we experience in ourselves. Nor can I or would I want to conceive of an individual that survives his physical death; let feeble souls, from fear or absurd egoism, cherish such thoughts. I am satisfied with the mystery of the eternity of life, and with the awareness and a glimpse of the marvelous structure of the existing world, together with the devoted striving to comprehend a portion, be it ever* *so tiny, of the Reason that manifests itself in Nature.*

from A. Einstein, "The world as I see it", *Forum and Century* **84**, 193-4 ((1930)

It is crucial to realize here that Einstein's ideas were in no sense compatible with any of the established religions of our time, or indeed of any time in the past. He felt a considerable affinity with a few religious figures of the past, but this was not because of their religious beliefs. In fact, Einstein was consistently and strongly opposed to both the claims and actions of organized religion. In his earlier years he said very little in public or in print about this, but after he acquired world-wide public fame in 1919-1920, he was often asked his opinions on spiritual and religious matters. As far as the beliefs and the metaphysical/epistemological doctrines that organized religions have to offer, he had this to say in 1922, in response to an interviewer:

Q.I: Do scientific and religious truths come from different points of view?

A: It is difficult even to attach a precise meaning to the term "scientific truth". Thus the meaning of the word "truth" varies according to whether we deal with a fact of experience, a mathematical proposition, or a scientific theory. "Religious truth" conveys nothing clear to me at all.

Q.II: Can scientific discovery enhance religious belief and repudiate superstition, since religious feelings can give impetus to scientific discovery?

A. Scientific research can reduce superstition, by encouraging people to think and view things in terms of cause and effect. Certain it is that a conviction, akin to religious feeling, of the rationality or intelligibility of the world lies behind all scientific work of a high order.

Q.III: What is your understanding of God?

A. This firm belief, a belief bound up with deep feeling, in a superior mind that reveals itself in the world of experience, represents my conception of God. In common parlance this may be described as "pantheistic" (Spinoza).

Q.IV: What is your opinion regarding a 'saviour?

A. Denominational traditions I can only consider historically and psychologically; they have no other significance for me."

Questions from a Japanese scholar on Dec 14, 1922, published in *Kaizo* **5**, no. 2, 197 (1923);
and in *Gelegentliches*, 1929 (on Einstein's 50th birthday).

His attitude on these questions hardly varied throughout his subsequent years, either in newspaper interviews, published articles, conversations with individuals, or in private correspondence. A typical example is the following, from only 3 years before he died:

"*My feeling is religious insofar as I am imbued with the insufficiency of the human mind to understand more deeply the harmony of the universe which we try to formulate as 'laws of Nature'. The idea of a personal God is quite alien to me and seems even naive*"

letter to Beatrice Frohlich, Dec 17, 1952 (Einstein archive 59-797)

From these remarks we see clearly that Einstein's faith had both a spiritual dimension (these are after all, not just beliefs about how the universe is, but also about how he felt about it, and his relationship to it), and an epistemological dimension (in that he linked this faith to the scientific pursuit of how the universe really is, and how science should be done). As we shall see, he felt clearly that without this faith, he would have been completely unable to make the discoveries that he did. This feeling, on his part, partly just involved the usual feeling that one cannot pursue with any real conviction a course of action or a line of research, without some set of beliefs. These beliefs not only motivate but also guide one in any course of action or research. However it also had a more epistemological side, in that Einstein felt (in ways perhaps influenced by Kant) that to have any kind of understanding at all one needed some such faith. On the purely epistemological plane Einstein was, of course, aware of the imperfect nature of all our knowledge and understanding, but nevertheless he felt that a belief in what he called 'cosmic religion' was essential to any kind of real science. Indeed, it is clear that he felt that a belief of this kind actually 'bootstrapped' one to a new plane of thought, in which one could engage in some sort of dialogue with Nature on very deep questions, questions often thought to be philosophical. In this exalted plane, any doubt in the cosmic religion, and in the cosmic order it implied, was not an option. Note that Einstein did not feel that there was any mysticism inherent in this faith (indeed, on many occasions he strongly deplored mysticism as childish, and irreconcilable with his ideas and beliefs). Rather he felt that:

"*I have never imputed to Nature a purpose or goal, or anything that could be understood as anthropomorphic. What I see in Nature is a magnificent structure that we can comprehend only very imperfectly, and that must fill a thinking* *person with a feeling of humility. This is a genuine religious feeling that has nothing to do with mysticism.*"

conversation with Ugo Onufri, 1955 (from Einstein archive 60-758).

Nor was Einstein oblivious of the impossibility of justifying this faith in any rational way – his reading of Hume and Kant would have made him acutely aware of this, if he had not reached the same conclusion by himself already. Indeed, in a conversation with the well-known Indian mystic Tagore he made this point of view very clear:

"*There are 2 different conceptions about the nature of the universe: (i) the world as a unity dependent on humanity; and (ii) the world as a reality independent of the the human factor. I cannot prove scientifically that Truth must be conceived of as a truth independent of humanity, but I firmly believe it...if there is a truth independent of Man, there is also a truth relative to this reality...The problem begins with whether Truth is independent of our consciousness.*"

From a conversation with the Indian mystic Rabindranath Tagore,
published *New York Times magazine*, Aug 10, 1930.

Nevertheless the striking success of his theories, and the enormous creative effort he had had to make to finally arrive at the definitive form of the General Theory of Relativity, had an enormous impact on him. We see the extent of the effort he made, in some well-known remarks he made in hindsight, many years after the theory had been formulated:

"*In the light of the knowledge obtained, the happy achievement seems almost a matter of course, and any intelligent student can grasp it without too much trouble. But the years of anxious searching in the dark, with their intense longing, their alternations of confidence and exhaustion and the final emergence into the light – only those who have experienced it can understand that.*"

from a lecture at the University of Glasgow, June 20, 1933;
published in "Notes on the origin of the General theory of Relativity", in "*Mein Weltbild*", 1931

Note here that by the time Einstein made these remarks, the theory was hardly doubted by the science community, and it may well have been true that perhaps a few students found the theory relativity easy to understand! However this confidence on Einstein's part, in the validity of the theory, did *not* come from its acceptance by the community – indeed, in a famous conversation, Einstein made clear that once he had the theory, and had confirmed that it gave the correct motion for the perihelion of Mercury, he was absolutely *sure* that is was correct:

"Suddenly Einstein handed me a cable that he took from the window-sill, with the words: "*this may interest you*". It was Eddington's cable with the results of the famous eclipse expedition. Full of enthusiasm, I exclaimed, "*how wonderful, this is almost the value you calculated!*". Quite unperturbed, he remarked "*I knew that the theory is correct. Did you doubt it?*". I answered, "*No, of course not. But what you have said if there had been no confirmation like this?*" He replied, "*I would feel sorry for the good Lord. The theory is correct anyway*"

from I Rosenthal-Schneider, "*Reality and Scientific Truth*" (Wayne State University Press, 1980)

Now one can of course put this last remark down to an Einstein carried away by elation, inspired by his own theory. This would be a natural reaction on his part, and indeed there is no doubt that this is how he felt (indeed, he remarked at the time, and also later, that the 3 days after he had finally found the theory, and shown that it gave the correct perihelion motion of Mercury, were for him the most ecstatic in his entire life). But on many other occasions Einstein also made remarks indicating how ineluctably profound and deeply held was his faith in the rational universe, and in his own ideas about it. This we really have to take seriously the impression that his 'cosmic faith' was for him indivisible and absolute. This raises of course acute epistemological problems, which we will come to presently.

Since it is often asserted that Einstein was sympathetic in some ways to organized religion (this is often done with the support of misquotations, or even pure fantasies about what he said), it is useful to look at a recently discovered letter, which makes his views very clear :

... The word God is for me nothing more than the expression and product of human weaknesses, the Bible a collection of honorable, but still primitive legends which are nevertheless pretty childish. No interpretation no matter how subtle can (for me) change this. These subtilized interpretations are highly manifold according to their nature and have almost nothing to do with the original text. For me the Jewish religion like all other religions is an incarnation of the most childish superstitions. And the Jewish people to whom I gladly belong and with whose mentality I have a deep affinity have no different quality for me than all other people. As far as my experience goes, they are also no better than other human groups, although they are protected from the worst cancers by a lack of power. Otherwise I

cannot see anything "chosen" about them.

In general I find it painful that you claim a privileged position and try to defend it by two walls of pride, an external one as a man and an internal one as a Jew. As a man you claim, so to speak, a dispensation from causality otherwise accepted; as a Jew the privilege of monotheism. But a limited causality is no longer a causality at all, as our wonderful Spinoza recognized with all incision, probably as the first one. And the animistic interpretations of the religions of nature are in principle not annulled by monopolization. With such walls we can only attain a certain self-deception, but our moral efforts are not furthered by them. On the contrary.

Now that I have quite openly stated our differences in intellectual convictions it is still clear to me that we are quite close to each other in essential things, ie., in our evaluations of human behavior. What separates us are only intellectual "props" and "rationalization" in Freud's language. Therefore I think that we would understand each other quite well if we talked about concrete things.

With friendly thanks and best wishes.

Yours,

A. Einstein

from a letter to Eric Gutkind, from Albert Einstein (Jan 3, 1954).
(Letter sold at auction in London, UK, for $\$404,000.00US$, May 16, 2008).

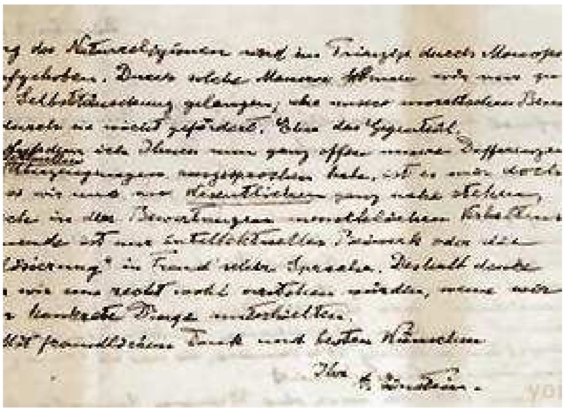

FIG. 2: A copy of the end of the letter quoted in the text, from Einstein to Eric Gutkind (Jan 3, 1954) in which Einstein spelt out to Gutkind his attitude to organized religion. This letter was sold at auction in 2008 for the equivalent of $\$404,000.00US$

As the above quotations show, Einstein never wavered in his attitude towards organized religion of any stripe - he felt it to be based ultimately on fear, and to be of interest purely as a cultural phenomenon. In fact on several occasions he went out of his way to distinguish several motivational features of religious thought, viz. (i) the motivation of fear of the unknown and of the hostile world around, and of death (ii) the motivation of a desire for love and support; and (iii) a deep sense of awe and mystery about the universe. He felt that the first two were primitive, and lead to an anthropomorphic concept of God; whereas the third was more mature, and more in harmony with a scientific spirit of inquiry.

Notice that the statements quoted so far say little about any moral side to Einstein's faith (ie., on questions about how things *ought* to be rather than how they are). As the above quotations show, Einstein never wavered in his attitude towards organized religion of any stripe - he felt it to be based ultimately on fear, and to be of interest purely as a cultural phenomenon. He felt that the dogmas of religion were not to be taken seriously, and that the idea of a God who addressed himself to human concerns was ridiculous (the most polite expression he used was 'naive'). Yet as we shall see in the next passage, his faith in cosmic order did have a moral side to it as well, in that a belief in it dictated how one should treat others, and also implied that humans needed to take responsibility for their own actions, instead of resorting to God as a guide:

.... Common to all these types [of belief] is the anthropomorphic character of their conception of God. Only individuals of exceptional endowments, and exceptionally high-minded communities, as a general rule, get in any real sense beyond this level. But there is a third state of religious experience which belongs to all of them, even though it is rarely found in a pure form, and which I will call cosmic religious feeling. It is very difficult to explain this feeling to anyone who is entirely without it, especially as there is no anthropomorphic conception of God corresponding to it.

The individual feels the nothingness of human desires and aims and the sublimity and marvelous order which reveal *themselves both in nature and in the world of thought. He looks upon individual existence as a sort of prison and wants to experience the universe as a single significant whole. The beginnings of cosmic religious feeling already appear in earlier stages of development–e.g., in many of the Psalms of David and in some of the Prophets. Buddhism, as we have learnt from the wonderful writings of Schopenhauer especially, contains a much stronger element of it.*

The religious geniuses of all ages have been distinguished by this kind of religious feeling, which knows no dogma and no God conceived in man's image; so that there can be no Church whose central teachings are based on it. Hence it is precisely among the heretics of every age that we find men who were filled with the highest kind of religious feeling and were in many cases regarded by their contemporaries as Atheists, sometimes also as saints. Looked at in this light, men like Democritus, Francis of Assisi, and Spinoza are closely akin to one another.

How can cosmic religious feeling be communicated from one person to another, if it can give rise to no definite notion of a God and no theology? In my view, it is the most important function of art and science to awaken this feeling and keep it alive in those who are capable of it. We thus arrive at a conception of the relation of science to religion very different from the usual one. When one views the matter historically one is inclined to look upon science and religion as irreconcilable antagonists, and for a very obvious reason. The man who is thoroughly convinced of the universal operation of the law of causation cannot for a moment entertain the idea of a being who interferes in the course of events–that is, if he takes the hypothesis of causality really seriously. He has no use for the religion of fear and equally little for social or moral religion. A God who rewards and punishes is inconceivable to him for the simple reason that a man's actions are determined by necessity, external and internal, so that in God's eyes he cannot be responsible, any more than an inanimate object is responsible for the motions it goes through. Hence science has been charged with undermining morality, but the charge is unjust. A man's ethical behaviour should be based effectually on sympathy, education, and social ties; no religious basis is necessary. Man would indeed be in a poor way if he had to be restrained by fear and punishment and hope of reward after death.

It is therefore easy to see why the Churches have always fought science and persecuted its devotees. On the other hand, I maintain that cosmic religious feeling is the strongest and noblest incitement to scientific research. Only those who realize the immense efforts and, above all, the devotion which pioneer work in theoretical science demands, can grasp the strength of the emotion out of which alone such work, remote as it is from the immediate realities of life, can issue. What a deep conviction of the rationality of the universe and what a yearning to understand, were it but a feeble reflection of the mind revealed in this world, Kepler and Newton must have had to enable them to spend years of solitary labour in disentangling the principles of celestial mechanics! Those whose acquaintance with scientific research is derived chiefly from its practical results easily develop a completely false notion of the mentality of the men who, surrounded by a sceptical world, have shown the way to those like-minded with themselves, scattered through the earth and the centuries. Only one who has devoted his life to similar ends can have a vivid realization of what has inspired these men and given them the strength to remain true to their purpose in spite of countless failures. It is cosmic religious feeling that gives a man strength of this sort. A contemporary has said, not unjustly, that in this materialistic age of ours the serious scientific workers are the only profoundly religious people.

from A Einstein, "Religion and Science", New York Times magazine, Nov. 9th, 1930

This last passage is a fairly complete summary of his views on the relationship of conventional morality and religious views to his own faith. We notice that the scientist is not without responsibility in this picture – both to follow the faith, and perhaps to defend it as well. Lest one be left in any doubt on how he felt about the relationship to his ideals and those of orthodox religion, it is useful to look at some later remarks. A typical example:

Whoever has undergone the intense experience of successful advances made in this domain [science] is moved by profound reverence for the rationality made manifest in existence. The further the spiritual evolution of mankind advances, the more certain it seems to me that the path to genuine religiosity does not lie through the fear of life, and the fear of death, and blind faith, but through striving after rational knowledge.

from A Einstein. "*Ideas and Opinions*" (Crown publishers, 1954)

It is of course well known that Einstein, in his later years, spent much time on humanitarian causes, as well as on attempting to promote the cause of world peace, where he felt this was appropriate – or influencing politicians to go to war, as in his famous letter to FD Roosevelt, advising the construction of atomic weapons to stop the Nazis from acquiring them. Thus one might imagine that he may have changed his ideas on the relationship of his cosmic faith to moral obligations later on. However this was not the case – and lest one be in any doubt on how he felt about moral obligations in what he called the 'human sphere', the following later reamrks make this clear:

"*Whatever there is of God and goodness in the universe, it must work itself out, and express itself through us. We cannot stand aside and let God do it*" from a recorded conversation with Algernon Black, fall 1940 (Einstein archive 54-834)

To the end, Einstein felt that human ideas about God had nothing to do with any prime mover of the universe, of which he felt we knew almost nothing. And, for him, this inevitably meant that all questions of morality were to be handled by us, without any callow or hypocritical appeal to God for guidance or justification.

Elsewhere, in the notes on Einstein the man, I go into the topic of his moral beliefs in more detail. However, before leaving the topic of his 'cosmic faith', it is worthwhile emphasizing the epistemological problems Einstein's beliefs generate. Foremost of these problems is one of which he must have been aware: that an unalloyed faith in Reason is ultimately self-contradictory. This is easy to see - if we follow the arguments of Reason, we quickly arrive at the conclusion that there are no certain truths about the empirical world (as Hume did), and that there are inevitably severe limits to our knowledge and to our understanding of anything, including the world (as Einstein and many others have done). And one conclusion that we may then immediately deduce from this, is that the proposition that the universe is itself rational, or subject to Reason, is clearly not demonstrable either empirically or by Reason alone. Indeed Reason tells us that we cannot be sure of this at all. Thus the idea that the universe is itself rational cannot be arrived at by rational means, and the assertion – that the universe *must* be rational – in fact contradicts Reason. Thus we may say that unreserved Faith in Reason leads to the self-negating conclusion that the Faith itself is unjustified.

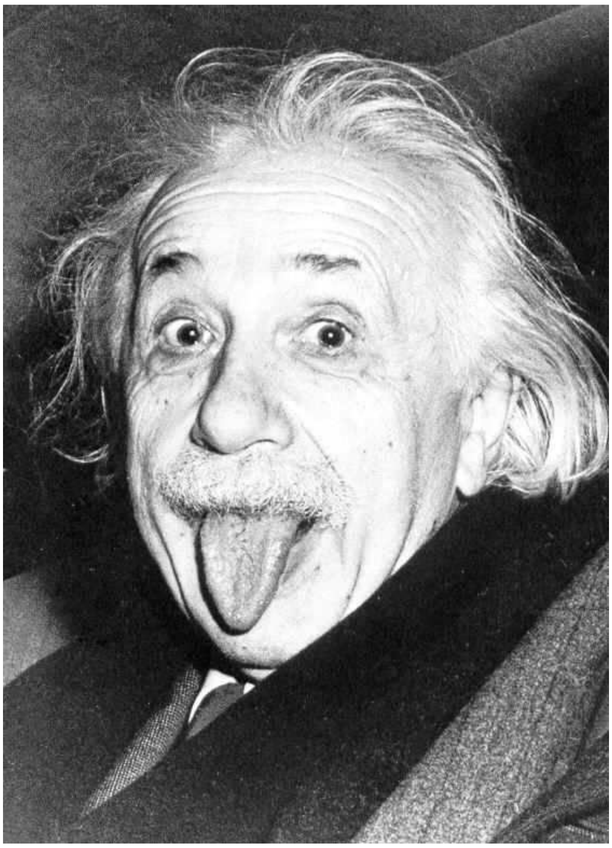

FIG. 3: A famous photograph taken of Einstein upon his arrival in the USA to become an American citizen. His irreverent attitude, displayed here to waiting photographers, was also occasionally displayed towards quantum mechanics, and towards a number of other problems he felt to be beyond his ability to understand.

That Einstein understood such an argument can hardly be doubted, given the remarks he often made on how limited our understanding would always remain. That he had any kind of sensible resolution to it is perhaps less clear - perhaps ultimately he adopted towards this question the same insouciant attitude that he adopted towards other questions that may remain forever unresolved by us - by occasionally laughing at it. However this question figures large in both the philosophical influences that were important for him, and in the philosophical ideas he formulated in response, which we now discuss in detail.

2 . EPISTEMOLOGY

It is hard for any working scientist not to have epistemological views, which inevitably are strongly influenced by his or her scientific work. However most scientists engage in very little conscious study of these epistemological underpinnings of their field of interest. There are reasons for this - apart from the fact that scientists typically have little time or inclination to make such a study, they often feel that they can get by with a fairly simple understanding; and moreover, that too deep a study might even hamper them in their scientific work. This is a legitimate point of view - but the dangers inherent in it were pointed out long ago in a different context by the mathematician and economist JM Keynes, who remarked that "*Practical men, who believe themselves to be quite exempt from any intellectual influence, are usually the slaves of some defunct economist. Madmen in authority, who hear voices in the air, are distilling their frenzy from some academic scribbler of a few years back*". And indeed one finds that the underlying epistemology of practising physicists, which strongly influences their work in spite of themselves, is typically distilled from one or other philosophical movement (in North America and the UK in the last 50 years, this has typically been some mixture of 18th-century British Empiricism and Popperian ideas on falsification). And so one can equally argue that too naive an allegiance to an outdated epistemology can also hamper one's scientific work.

The attitude of Einstein to philosophy and its relation to his work was very different from that of the average scientist. Not only was he very familiar with the views of several important philosophers, and had studied them carefully, he also considered his philosophical thinking to be very much allied to, indeed a part of, his more purely scientific work. They went hand in hand, and his philosophical views developed and changed along with his scientific discoveries. At no time in Einstein's career did he ever take these philosophical connections for granted; consequently, he from time to time spelt out the philosophical basis of his thinking, and we can therefore follow his philosophical development in some detail.

In what follows we consider how his epistemological credo developed, and the influence that other thinkers had on it; and we consider the resulting mature epistemology that came out of this. In doing so it is also necessary to explore the connections with his developing scientific opus - many of the details of this are also discussed elsewhere in these notes. One thing I will not discuss much, however, is the connection with Einstein's experimental work. The role of this in shaping his attitudes is often neglected (possibly because most of the people that have written about Einstein's ideas have not themselves been involved in experiments; and because Einstein himself did not often speak of his own experimental work). But in fact one thing that radically distinguishes Einstein from the vast majority of theoretical physicists and philosophers (then and now) is that he really did understand experiments, and he knew his way very well around a lab. One sees this very clearly in his essays and papers - his physical intuition for the whole range of physical and chemical phenomena studied at that time, as well as for the natural phenomena all around us, is everywhere evident. It is quite ironic that he is often criticized by modern theoretical physicists (even string theorists!) for having adopted a too mathematical approach in his later work - yet few of these modern writers have anything like the intuitive understanding or hands-on experience of natural phenomena that Einstein possessed.

2.1. The INFLUENCE of OTHER THINKERS.

Naturally Einstein was aware of, and influenced by, the work of other thinkers in formulating his attitudes; indeed, as noted already, much of his early reading included philosophers as well as scientists. From even the very early stages of his work, it is clear that for him physics was inextricably connected with deeply philosophical issues. He was acutely aware of the conceptual difficulties raised by the uncertain and imperfect knowledge given to us by our perceptions, and of the weaknesses in the philosophical doctrines of his day.

In his earlier years he was strongly influenced by the views of the British empiricists, notably Hume, and by the positivist philosopher/physicist Ernst Mach. He was well aware of the influence of 'empirical philosophy' on the work of Newton (and to a lesser extent on Maxwell), and of the important role it had played in the remarkable experimental advances (by Galileo, Faraday, etc.), that had occurred in the three previous centuries. His reading of these authors taught him that even very basic ideas we have about the real world, such as causality, or the idea of a world external to ourselves, were in no sense inevitable, and could not be taken for granted. However, even though some positivists like Schlick later tried to adopt Einstein as one of their own, it is clear that at no stage, even in the early days of relativity (from, eg., 1905-1907) did Einstein ever fully adopt the idea that our perceptions, or (to use the British phrase) our 'sense data', are in any sense the most primitive objects of perception. In this it seems likely that in his earlier days Einstein was influenced at least by his boyhood study of Greek contributions to philosophy and mathematics; and later on by the ideas of Kant, which were common knowledge, at least in popularized form, in the German-speaking world of that time.

However one might wish to assimilate Einstein's ideas to one or other philosophical movement, I emphasize again that the ideas of the philosophers whom he read were simply a few of the ingredients involved in the development of his own views, which were of course strongly influenced, as time went on, by his own discoveries. It seems that at all times he was aware of the defects of naive realism, of both positivism and empiricism, and of idealistic philosophies;

his own ideas were thus inevitably different from any of these.

We begin by looking at what Einstein said about some of these philosophical doctrines. We start with Empiricism; recall that this doctrine asserts that we can start with 'sensory impressions', or 'sense data', as the primitive 'stuff' of human knowledge, and it reached, in the hands of Hume, a completely sceptical conclusion about the veracity of all our general ideas and concepts about the world. Einstein had lots to say about this:

"*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. Hume has permanently influenced the development of the best philosophers who came after him. One senses him in the reading of Russell's philosophical analyses, whose acumen and simplicity of expression have often reminded me of Hume.*

Man has an intense desire for assured knowledge. That is why Hume's clear message seems crushing: the sensory raw material, the only source of our knowledge, through habit may lead us to belief and expectation but not to the knowledge and still less to the understanding of lawful relations. Then Kant took the stage with an idea which, though certainly untenable in the form in which he put it, signified a step towards the solution of Hume's dilemma: whatever in knowledge is of empirical origin is never certain (Hume). If, therefore, we have definitely assured knowledge, it must be grounded in reason itself. This is held to be the case, for example, in the propositions of geometry and in the principle of causality. These and certain other types of knowledge are, so to speak, a part of the implements of thinking and therefore do not previously have to be gained from sense data (i. e., they are a priori knowledge). 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."

Extract from Albert Einstein, "Remarks on Bertrand Russell's Theory of Knowledge"
From "The Philosophy of Bertrand Russell", Vol. V of "The Library of Living Philosophers,"
edited by Paul Arthur Schilpp, 1944.

We see already, from this passage, that Einstein felt that Kant had at least gone some way towards dissolving the dilemma posed by Hume's work – we shall look more below at Einstein's views on Kant. Einstein admired some aspects of British empiricism, notably its disposal of naive realism:

"*The overcoming of naive realism has been relatively simple. In his introduction to his volume, An Inquiry Into Meaning and Truth, Russell has characterized this process in a marvelously concise fashion:*

"We all start from "naive realism," i. e., the doctrine that things are what they seem. We think that grass is green, that stones are hard, and that snow is cold. But physics assures us that the greenness of grass, the hardness of stones, and the coldness of snow are not the greenness, hardness, and coldness that we know in our experience, but something very different. The observer, when he seems to himself to be observing a stone, is really, if physics is to be believed, observing the effects of the stone upon himself. Thus science seems to be at war with itself: when it most means to be objective, it finds itself plunged into subjectivity against its will. Naive realism leads to physics, and physics, if true, shows that naive realism is false. Therefore naive realism, if true, is false; therefore it is false. (pp. 14-15)" "

Extract from Albert Einstein, "Remarks on Bertrand Russell's Theory of Knowledge"
From "The Philosophy of Bertrand Russell", Vol. V of "The Library of Living Philosophers,"
edited by Paul Arthur Schilpp, 1944.

However Einstein was not about to let the empiricists off the hook; indeed, he felt that they had clearly failed to deal with the internal contradictions in their own arguments:

"*...by his clear critique Hume did not only advance philosophy in a decisive way but also – though through no fault of his – created a danger for philosophy in that, following his critique, a fateful "fear of metaphysics" arose which has come to be a malady of contemporary empiricistic philosophizing; this malady is the counterpart to that earlier philosophizing in the clouds, which thought it could neglect and dispense with what was given by the senses.*

No matter how much one may admire the acute analysis which Russell has given us in his latest book on Meaning and Truth, it still seems to me that even there the specter of the metaphysical fear has caused some damage. For this fear seems to me, for example, to be the cause for conceiving of the "thing" as a "bundle of qualities," such that the "qualities" are to be taken from the sensory raw material. Now the fact that two things are said to be one and the same thing, if they coincide in all qualities, forces one to consider the geometrical relations between things as belonging to their qualities. (Otherwise one is forced to look upon the Afield Tower in Paris and a New York skyscraper as "the *same thing.")* However, I see no "metaphysical" danger in taking the thing (the object in the sense of physics) as an independent concept into the system together with the proper spatio-temporal structure.*

In view of these endeavours I am particularly pleased to note that, in the last chapter of the book, it finally turns out that one can, after all, not get along without "metaphysics." The only thing to which I take exception there is the bad intellectual conscience which shines through between the lines."

* Compare Russell's An Inquiry Into Meaning and Truth, 119-120, chapter on "Proper Names."

Extract from Albert Einstein, "Remarks on Bertrand Russell's Theory of Knowledge"
From "The Philosophy of Bertrand Russell", Vol. V of "The Library of Living Philosophers,"
edited by Paul Arthur Schilpp, 1944.

Even Newton, for whom Einstein had otherwise an unreserved admiration, was not immune to criticism on this point. We have already seen (see Notes on Newton) that Newton followed the Empiricist idealogy laid out by Francis Bacon in a remarkably uncritical way - and that this to some extent prevented him from gaining insights into the nature of light. On this, Einstein remarked:

The notion "material point" is fundamental for mechanics. If now we seek the mechanics of a bodily object which itself can not *be treated as a material point – and strictly speaking every object "perceptible to our senses" is of this category – then the question arises: How shall we imagine the object to be built up out of material points, and what forces must we assume as acting between them? The formulation of this question is indispensable, if mechanics is to pretend to describe the object* completely.

It is natural to the tendency of mechanics to assume these material points, and the laws of forces acting between them, as invariable, since time alterations would lie outside of the scope of mechanical explanation. From this we can see that classical mechanics must lead us to an atomistic construction of matter. We now realize, with special clarity, how much in error are those theorists who believe that theory comes inductively from experience. Even the great Newton could not free himself from this error ("Hypotheses non fingo").**

** "I make no hypotheses"

from A. Einstein, 'Physics and Reality', J. Franklin Inst. **221**, 349-382 (1936)

It is curious to look back from the early 21st century to these passages. At the time Einstein wrote them, 20th century British analytic philosophy was still on the rise, under the stimulus of Russell, Moore, and the Vienna logical positivists (and of course, following the much older tradition of radical British empiricism). Russell was already in the process of abandoning parts of this approach, partly under the stimulus of the enormous changes taking place in physics; but it is not clear that he would ever fully appreciate what Einstein was saying here. Eventually, by the late 1950's, the British analytic approach had evolved into the fatuously sterile school of linguistic philosophy, in the hands of Wittgenstein, JL Austin, RM Hare, and their followers. By this time, Einstein was already dead, and Russell, in complete disgust, had lost all interest in his progeny (remarking that the linguistic philosophers had completely abandoned the essential task of philosophy - which, for him, was to understand the world - in favour of understanding only sentences). But even in spite of this, Russell himself never really was able to detach himself sufficiently from his logico-empiricist roots to fully grasp the enormously important metaphysical underpinnings of all of science. And it has to be said that the same is true of much of subsequent philosophy in the Anglo-American world, which continues to focus on the importance of experiment, at the expense of the theoretical framework within which all experiments are defined and and analyzed, and from which they acquire much of their meaning and justification.

As we have seen already, in the discussion on Einstein's 'cosmic faith', the metaphysical foundations of physics were felt to be absolutely essential by Einstein. While he fully shared with both the empiricists and the positivists their beliefs in reason and in empirical evidence, he understood very clearly something they did not, viz., that these beliefs really were *faiths*, which could not themselves be justified by rational or empirical means. Consequently, he saw clearly that physics, insofar as it was based on rational and empirical foundations, must inevitably also find itself standing on metaphysical roots.

Einstein's criticisms of the philosophical views of of his time were certainly not reserved to the ideas of British philosophers. Indeed, the abandonment of metaphysics was even more obvious in the ideas of the continental logical positivists - they entirely rejected any metaphysical arguments as being unverifiable, and therefore, according to them, completely meaningless. One should not forget that at the time Einstein was active, the positivist doctrine had not settled down - it later came to be associated with the Vienna school, whose views were rather rigid, but it had been formulated long before this, as an idea by Saint-Simon, in the writings of Comte, and in the work of Ernst Mach. Key emphasis was laid on the assertion that a proposition could only acquire meaning through the possibility and means of its verification, in the world we experience via our perceptions - again, sense data were taken to be primordial here.

The work of Mach had an important influence on Einstein, notably in the formulation of the Special Theory of Relativity, although he later came to see the defects in Mach's position. The intellectual debt that the special theory of relativity owed to Mach is well known. Mach's strong critique of Newton's ideas of space and time, his insistence that one could only meaningfully discuss these concepts in terms of physical operations such as measurements (and that only relative motion had any meaning), helped Einstein in 1905 to understand that one had to redefine completely the notions of time and space to deal with the principle of relativity that he had formulated. Later on, during and after his formulation of the General Theory, he was strongly influenced for a while by what he called 'Mach's principle', viz., that any phenomenon that would seem attributable to absolute space and time (eg. inertia, or centrifugal force) should instead be seen as emerging from the large scale distribution of matter in the universe. Einstein's acknowledgement, of the influence on him of some of Mach's ideas at this time, is well documented (for example in his eulogy to Mach at the occasion of his death in 1916). However it is it is hard to imagine that Einstein ever took Mach's philosophy seriously as a whole, notably Mach's insistence that only observable phenomena are real. Certainly this seems unlikely after Einstein's demonstration in 1905 of the validity of the atomic hypothesis, in his famous paper on Brownian motion (Mach had strongly opposed Boltzmann's ideas on atoms, arguing that because they were unobservable they could not be held to exist). By 1922 Einstein was expressing himself unreservedly on this:

"*Mach was as good a scholar of mechanics as he was a deplorable philosopher*"
quote reprinted in Nature **112**, 253 (1923)

Ironically, Einstein's Special and General Theories had a large impact on the subsequent development of logical positivism, notably on the work of Reichenbach and Carnap, as well as on the development of the 'falsificationist' position of Popper. Even before the Special Theory, the great mathematician Poincaré (one of the major players in the development of early ideas on how to reconcile electrodynamics with Newtonian ideas) had developed his own brand of these positivist ideas, which became known as 'conventionalism' (ie., the idea that geometries, and more generally the various means of defining physical quantities, could be chosen in many different ways, and should thus be chosen in such a way as to make the application of theories as simple as possible).

Einstein addressed himself to all of these ideas in various ways in his later years. In one well-known passage he imagines a conversation between Poincaré, Reichenbach, and a "non-positivist":

"*Let us first take a good look at the question: Is a geometry looked at from the physical point of view verifiable (viz., falsifiable) or not? Reichenbach, together with Helmholtz, says: Yes, provided that the empirically given solid body realises the concept of distance. Poincaré says no and consequently is condemned by Reichenbach. Now the following short conversation takes place:*

Poincaré: *The empirically given bodies are not rigid, and consequently can not be used for the embodiment of geometric intervals. Therefore, the theorems of geometry are not verifiable.*

Reichenbach: *I admit that there are no bodies which can be immediately adduced for the real definition of the interval. Nevertheless, this real definition can be achieved by taking the thermal volume-dependence, elasticity, electro- and magnetostriction, etc., into consideration. That this is really [and] without contradiction possible, classical physics has surely demonstrated.*

Poincaré: *In gaining the real definition improved by yourself you have made use of physical laws, the formulation of which presupposes (in this case) Euclidean geometry. The verification, of which you have spoken, refers, therefore, not merely to geometry but to the entire system of physical laws which constitute its foundation. An examination of geometry by itself is consequently not thinkable. Why should it consequently not be entirely up to me to choose geometry according to my own convenience (i.e., Euclidean) and to fit the remaining (in the usual sense physical) laws to this choice in such manner that there can arise no contradiction of the whole with experience?*

(The conversation cannot be continued in this fashion because the respect of the [present] writer for Poincarés superiority as thinker and author does not permit it; in what follows therefore, an anonymous non-positivist is substituted for Poincaré.)

Reichenbach: *There is something quite attractive in this conception. But, on the other hand, it is noteworthy that the adherence to the objective meaning of length and to the interpretation of the differences of co-ordinates as distances (in pre-relativistic physics) has not led to complications. Should we not, on the basis of this astounding fact, be justified in operating further at least tentatively with the concept of the measurable length, as if there were such things as rigid measuring-rods. In any case it would have been impossible for Einstein de facto (even if not theoretically) to set up the theory of general relativity, if he had not adhered to the objective meaning of length.*

Against Poincarés suggestion it is to be pointed out that what really matters is not merely the greatest possible simplicity of the geometry alone, but rather the greatest possible simplicity of all of physics (inclusive of geometry). This is what is, in the first instance, involved in the fact that today we must decline as unsuitable the suggestion to adhere to Euclidean geometry.

Non-Positivist: *If, under the stated circumstances, you hold distance to be a legitimate concept, how then is it with your basic principle (meaning = verifiability) ? Do you not have to reach the point where you must deny the meaning of geometrical concepts and theorems and to acknowledge meaning only within the completely developed theory of relativity (which, however, does not yet exist at all as a finished product)? Do you not have to admit that, in your sense of the word, no meaning can be attributed to the individual concepts and assertions of a physical theory at all, and to the entire system only insofar as it makes what is given in experience intelligible? Why do the individual concepts which occur in a theory require any specific Justification anyway, if they are only indispensable within the framework of the logical structure of the theory, and the theory only in its entirety validates itself?*

It seems to me, moreover, that you have not at all done justice to the really significant philosophical achievement of Kant. From Hume Kant had learned that there are concepts (as, for example, that of causal connection), which play a dominating role in our thinking, and which, nevertheless, can not be deduced by means of a logical process from the empirically given (a fact which several empiricists recognise, it is true, but seem always again to forget). What justifies the use of such concepts? Suppose he had replied in this sense: Thinking is necessary in order to understand the empirically given, and concepts and categories are necessary as indispensable elements of thinking. If he had remained satisfied with this type of an answer, he would have avoided scepticism and you would not have been able to find fault with him. He, however, was misled by the erroneous opinion, difficult to avoid in his time - that Euclidean geometry is necessary to thinking and offers assured (i.e., not dependent upon sensory experience) knowledge concerning the objects of external perception. From this easily understandable error he concluded the existence of synthetic judgments a priori, which are produced by the reason alone, and which, consequently, can lay claim to absolute validity. I think your censure is directed less against Kant himself than against those who today still adhere to the errors of 'a priori synthetic judgements'."

Einstein, in Schilpp, LLP, "reply to criticisms", p. 676 (1949)

Both the presentation and the result of this exchange are amusing - Einstein, as the non-positivist, has apparently forced both Poincaré and Reichenbach to the conclusion that, whether one adopts the conventionalist or the logical positivist point of view on the meaning of physical objects in a physical theory, it is not possible to define any of these objects, in the theory, without looking at the theory as a complete whole. Einstein's objections to this conclusion are (i) that no complete theory of physics exists (or ever has); and (ii) an unstated objection, implied in the foregoing, viz., that the conclusion is at variance with the facts. Since physicists (and non-physicists) clearly can talk intelligibly about clocks, atoms, etc., without appealing to the entire (incomplete) structure of physics at all times, the conclusion must clearly be false.

As time went on, Einstein's position against positivism hardened. This happened for several reasons. First, in response to his own questions about the nature of 'Physical Reality', he began to formulate his ideas much more precisely. These ideas developed under the stimulus of his extraordinary work on gravity and spacetime, but also in the light of all his other work: on what later became quantum mechanics, and on the research projects he had undertaken on a huge variety of other physical phenomena, both theoretical and experimental (even extending to the development of various electromagnetic devices which he patented). Second, Einstein came to appreciate more and more clearly the necessary role which *a priori* concepts have in our thinking, and as time went on he gradually developed a greater faith in the veracity of these. Finally, there came the clash between Einstein's views on physical reality, and the rather positivistic ideas that were developed by Bohr and others to interpret quantum phenomena, once the theory of quantum mechanics emerged in 1925-26.

A sample of Einstein's later reaction to positivistic ideas is as follows:

"....that which appears to me to be the programmatic aim of all physics: the complete description of any (real) situation (as it supposedly exists independently of any act of observation or substantiation). Whenever the positivistically-inclined modern physicist hears such a formulation, his reaction is that of a pitying smile. He say to himself: "there we have the naked formulation of a metaphysical prejudice, empty of content, a prejudice, moreover, the conquest of which constitutes the major epistemological achievement of physicists within the last quarter century. Has any man ever perceived a 'real physical situation'? How is it possible that a reasonable person could today still believe that he can refute our essential knowledge and understanding by drawing up such a bloodless ghost?"...."

Einstein, in Schilpp, LLP, "reply to criticisms", p. 667

The above remarks satirize the positivist position. In the discussion of quantum mechanics he very briefly summarized his position on the nature of reality, and on the defects of the positivist approach, as follows:

"*The entire alleged difficulty proceeds from the fact that one postulates something not observed as 'real' (this is the answer of the quantum theorist).*

What I dislike in this kind of argumentation is the basic positivistic attitude, which from my point of view is *untenable, and which seems to me to come to the same thing as Berkeleys principle,* esse est percipi. *Being is always something which is mentally constructed by us, that is, something which we freely posit (in the logical sense). The justification of such constructs does not lie in their derivation from what is given by the senses. Such a type of derivation (in the sense of logical deducibility) is nowhere to be had, not even in the domain of pre-scientific thinking. The justification of the constructs, which represent reality for us, lies alone in their quality of making intelligible what is sensorily given (the vague character of this expression is here forced upon me by my striving for brevity).* "

Einstein, in Schilpp, LLP, "reply to criticisms", p. 669

All of the foregoing makes it clear how similar Einstein's epistemological ideas were to those of Immanuel Kant. We have already seen that Einstein took some interest in the ideas of Kant. It is actually not clear to what extent he was influenced by Kant's work in his earlier years – many of Einstein's biographers have repeated the story that he studied Kant both as a young teenager and later at university (and that he had even read the "*Critique of Pure Reason*" as a young teenager). However these claims seem to me to be frankly a little improbable, and are moreover contradicted by some of his later writings. For example, looking back on his youth near the end of his life he wrote:

"*...I did not grow up in the Kantian tradition, but came to understand the truly valuable which is to be found in his doctrine, alongside of errors which today are quite obvious, only quite late. It is contained in the sentence: 'The real is not given to us, but put to us* (aufgegeben) *(by way of a riddle).' This obviously means: There is such a thing as a conceptual construction for the grasping of the inter-personal, the authority of which lies purely in its validation. This conceptual construction refers precisely to the 'real' (by definition), and every further question concerning the 'nature of the real' appears empty.*"

Einstein, in Schilpp, LLP, "reply to criticisms", p. 680 (1949)

and in a letter to Max Born in 1918 he wrote

"*....I am reading Kant's* "Prolegomena" *here, among other things, and I am beginning to comprehend the enormous suggestive power that emanated from the fellow, and still does. Once you concede to him merely the existence of synthetic* a priori *judgements, you are trapped. I have to water down the* 'a priori' *to 'conventional', so as not to have to contradict him, but even then the details do not fit. Anyway it is nice to read him, even if it is not as good as his predecessor Hume's work. Hume also had a far sounder instinct.*"

from a letter to Max Born, in Aug 1918

Curiously, Born regards these remarks as a demonstration that at that time Einstein was still under the spell of British empiricism, and that he only later came to demand that physical theories have a metaphysical foundation. This is probably true (in his autobiographical notes, published much later, Einstein noted that his mature epistemological ideas evolved only slowly, and did not correspond at all with the views he had adopted when younger). Nevertheless, in his later years Einstein made it clear that he approved of Kant's position, in spite of the obvious inconsistencies between Kant's conclusions on the nature of space and time, and the results of the theory of relativity. In particular, he noted that:

...If Kant had known what is known to us today of the natural order, I am certain that he would have fundamentally revised his philosophical conclusions. Kant built his structure upon the foundations of the world outlook of Kepler and Newton. Now that the foundation has been undermined, the structure no longer stands.

Interview with Chaim Tschernowitz, in "*The Jewish Sentinel*", Sept 1931, 19.

So what was it that Einstein thought was valuable in Kant's ideas? Let us recall one essential component of Kant's philosophy, viz., that all our ideas and concepts, including what would be called 'impressions', or 'perceptions', or 'sense data' by empiricists or positivists, have to be understood as a combination or amalgam of (i) elements from the real 'external' world and (ii) elements from our own mental and perceptual apparatus. His thesis was that experience of any kind would be logically impossible without both - that one requires both a world and a perceiver for experience to exist at all. Moreover, for there to be any differentiation or structure of any kind in this experience, one required certain mental 'categories' and 'a priori intuitions', which again were features of the mental/perceptual apparatus. Kant went so far as to list the 12 categories he felt were necessary, and also to argue that *a priori* intuitions of space and time were required. This was not to argue that these categories and intuitions corresponded to any structure in the 'real world' of "*noumena*"; we could never ever know what the real world was like. Instead Kant argued that this amalgam of *a priori* ideas and sense data, in what he called our "*representations*" of the world, required these categories and intuitions. These representations were thought of as being representations of phenomena - all our ideas, perceptions, and thinking refer to this phenomenological world, rather than the real world of noumena. The details of Kant's ideas are given in the notes devoted to his ideas. We do not require them here except to note that Kant assumed without question that Newton's theory was correct, and so accepted the structure of space and time inherent in Newton's theory. However, it follows inevitably from Kant's theory that space and time cannot be viewed as attributes of the real world, but only of the phenomenological world.

We have seen already in the quotes given above that Einstein basically agreed with this thesis - that Kant had in effect resolved the problems raised by Hume with this argument. Thus Einstein agreed that scientific theories were based on a synthesis of empirical results (in the form given to us as sense-data) and a priori concepts such as the idea of physical objects, existing in spacetime. Already by 1923 this was very clear to him:

What seems to me to be the most important thing in Kant's philosophy is that it speaks of a priori *concepts for the construction of science*

from A. Einstein, *Nature* **112**, 253 (1923)

These last remarks, along with the 1931 remarks to Tschernowitz, and the passage in the Schilpp volume, supply most of the key to Einstein's later approval of Kant's basic ideas. The idea, that Nature is put to us 'by way of a riddle', well describes Kant's basic attitude towards scientific research – articulated, eg., in the preface to the 2nd edition of the "*Critique of Pure Reason*", where he writes that "*Reason must approach Nature, indeed, with the view of receiving information from it – not, however, in the character of a pupil, who listens to all that his master chooses to tell him, but in that of a judge, who compels the witnesses to reply to those questions which he himself thinks fit to propose. To this single idea must the revolution be ascribed, by which, after groping in the dark for so many centuries, Natural Science was at length conducted into the path of certain progress*". This picture of science accorded very well with Einstein's. And it is hard to see how Einstein could have avoided the requirement of *a priori* concepts, which he even occasionally described using Kant's language of categories and intuitions.

However where Einstein felt Kant had been mistaken was in his assumption that one could, by analytic argument, actually discover what these categories and intuitions were. In fact, of course, Einstein's own work had completely overthrown the Newtonian picture of space and time, and replaced it with a new one. But it still left intact the ideas of space and time (or, rather, their synthesis in 'spacetime'). Did he then feel that the idea of spacetime was necessary for all experience, but nevertheless still nothing but a human creation, a representation of phenomena? In most of his writings this is the case, except that he often went further, arguing, as we shall see below, that even spacetime was nothing but a 'free invention of the mind', which was found to be appropriate to describing phenomena - there was still no inevitability to it. In short, Einstein felt that there was nothing inevitable about any of the categories - they could be altered at will to give a better picture of the phenomenological world. What he accepted without question was the Kantian thesis that one inevitably needed some logical structure, in the form of, eg., categories, or other kinds of *a priori* concept, to have any kind of physical theory at all.

We have seen that Einstein's stated views on the nature of physical reality evolved over time, and that there was an uneasy cohabitation between his faith in a rational universe (and sometimes in the complete veracity of his own theories about this universe), on the one hand, and his acceptance that Reason inevitably forced one to accept that the discoveries of science were in no sense final, or that they captured any kind of ultimate truth. It is in the light of this ambivalence that we now turn to his own lengthy epistemological views.

2.2 EPISTEMOLOGICAL CREDO

Before outlining Einstein's epistemological views, and allowing him to express them in his own way, let's first briefly summarize the philosophical situation as he found it, in the period 1900-1940 when he was in the process of developing these views. Much more detail on the following can be found in the course notes on British empiricism, and on Kant.

Almost every important Western philosopher since the time of Newton had been strongly influenced by the Newtonian revolution in physics. However physics, and to a lesser extent the other sciences, had also been very strongly affected by the philosophers – most notably by the ideas of the British empiricists, by Kant's attempt to deal with the almost fantastic opinions these seemed to engender, and by the even more extreme views of positivism which were largely stimulated by empiricism.

The key issue facing the philosophy of physics at this time was the question of how the empirical 'facts' of which we are all aware, and which by this time formed the cornerstone of physics, related to the 'real world'; and to what extent we could be sure of any of these facts. The problem had been put in its sharpest form by Hume, who showed that if one assumed that sense impressions and mental ideas formed the basic stuff of experience, and that this was all that we could know apart from *a priori* truths (not themselves dependent on experience), then even very basic notions such as causality or the existence of the 'self' were in no sense sure - for they were not part of experience, but rather were ideas foisted on experience by us. For Hume, our experience, which he understood in terms of 'sense impressions', was roughly analogous to Plato's images on the cave wall. All we could say, according to Hume, was that we might have inductive evidence for notions like causality, which could be negated at any time in the future.

The response of Kant to this – a response well-known to continental philosophers, and to many physicists, at that time – was to argue that our experience could not just be understood in terms of sense impressions. Such an approach was self-contradictory, since it implied that the sense data arose 'out of nothing'; clearly, if one accepted that there was some sort of 'reality', meaning 'everything that is' (whatever it might be), the sense impressions or perceptions, so defined, could only be an aspect of it, not the whole of it. Moreover, the assumption that one could analyze experience in terms of structures like 'sense data' was *already* an imposition of structure on the stuff of experience, that was no different in principle from the imposition of notions like causality or the 'self'.

But then, Kant argued, the possibility of *any kind of thinking at all* necessarily required that some structure be imposed on experience. The question then became, what conditions were required for thinking to be at all possible; and in particular, what kind of conditions were implied if the idea of reality was to be an object of our thought (ie., part of our thinking)? Kant's argument, the gist of which had been very influential on the European continent (but much less so in the Anglo-American world) was to argue that (i) the 'representations' (constituents of thought) required, for their very existence, a mental/perceptual apparatus on the part of the thinker, and (ii) a relationship between this apparatus and 'reality', whatever this reality might be. Kant argued that the world of the 'phenomena' of our thinking (the representations) was a result of in some way amalgamating the connections to the world of reality (the world of 'noumena') with our perceptual/mental apparatus. The real world of noumena was fundamentally inaccessible to us - all we could ever know was our own experience. For cognition to be involved in this experience – ie., for us to be able to think at all – Kant further required that a set of 12 basic 'categories' and 3 intuitions were necessary. Amongst the intuitions were those of space and time. Although the details of Kant's arguments were often quite obscure, his conclusion seemed to many to be very sensible. Roughly speaking, all our mental activity was the result of an interaction between our minds/senses on the one side, and the real world (including ourselves) on the other; our mental/perceptual apparatus was necessarily somewhat primitive and imperfect, and so necessarily incapable of fully grasping reality. And for thinking to be possible at all, some kind of 'internal structure' to our mental activity was required. Moreover, using these arguments one could rescue the notions of causality, and of the self (which, says Kant, we come to know through 'apperceptions', which require the notion of the 'self' to exist at all).

While many found Kant's conclusions quite compelling, the positivists rejected them completely, and indeed ultimately rejected any proposition whose terms could not be defined by some conceivable process of verification. The truth or falsity of logical propositions could be verified by the rules of logic, but empirical propositions were held to be meaningless unless some set of operations capable of deciding their truth could be defined in the real world. While there were many obvious problems associated with such a doctrine, it became more very influential in the time that Einstein worked. Moreover the views of Mach on the inadequacy of Newton's epistemology (notably on his introduction of ideas like absolute space and time, that were unverifiable and therefore meaningless) had a large influence on Einstein in his earlier years.

This then was the situation at the time Einstein worked. Now, as we have seen, Einstein's epistemological views changed rather dramatically over the years. In the period from 1900-1920 he was strongly influenced by his reading of Hume and Mach, and more generally by the empiricist philosophy – and he found certain parts of positivism useful even if he did not adopt the positivist doctrines. It is probably fair to say that at this time Einstein was more interested in some of the positivist ideas as intellectual tools (notably in his adoption of 'Thought Experiments' as a means of formulating principles), rather than as forming a coherent doctrine in their own right. However there is no question that his gradual realization of the independent nature of the spacetime metric in General Relativity, and the deep problems raised by quantum mechanics, forced Einstein to rethink all of this, beginning already well before 1920. The resulting set of mature philosophical ideas is much more interesting, and we will focus mostly on these in what follows.

It is useful to begin with the famous set of autobiographical notes that Einstein wrote for the Schilpp volume devoted to his ideas. In these he recalls the development of his thinking from when he was a child, right up to the work of his later years. Characteristically, this account is woven together with his reflections on the nature of cognition, as well as with his philosophical views. We have already seen the importance Einstein attached to this discussion of the primitive nature of all our thinking - now we can see how this integrates into the formation of both his initial learning experiences as a child, and the emergence of his later philosophical credo, which he states here very succinctly:

What, precisely, is 'thinking'? When, at the reception of sense impressions, memory-pictures emerge, this is not yet 'thinking'. And when such pictures form series, each member of which calls forth another, this too is not yet 'thinking'. When, however, a certain picture turns up in many such series, then – precisely through such return – it becomes an an ordering element for such series, in that it connects series which are in themselves unconnected. Such an element becomes an instrument, a concept. I think that the transition, from free association or 'dreaming' *to thinking, is characterized by the more or less dominating role which the 'concept' plays in it. It is by no means necessary that a concept must be connected with a sensorily cognizable and reproducible sign (word); but when this is the case, thinking becomes by means of that fact communicable.*

With what right – the reader will ask – does this man operate so carelessly and primitively with ideas, in such a problematic realm, without making even the least effort to prove anything? My defense: all our thinking is of this nature, of a free play with concepts; the justification for this play lies in the measure of its survey, over the experience of the senses, which we are able to achieve with its aid. The concept of 'truth' can not yet be applied to such a structure; to my thinking this concept can come into question only when a far-reaching agreement or convention concerning the elements and rules of the game is already at hand.

For me it is without doubt that that our thinking goes on for the most part without use of signs or words, and beyond that to a considerable degree unconsciously. For how, otherwise, should it happen that sometimes we 'wonder' quite spontaneously about some experience? This 'wondering' seems to occur when an experience comes into conflict with a world of concepts which is already sufficiently fixed within us. Whenever such a conflict is experienced strongly and intensely, it reacts back on our 'thought world' (Gedankenwelt) *in a decisive way. The development of this thought world is in a certain sense a continuous flight from 'wonder'.*

A wonder of such nature I experienced as a child of 4 or 5 years, when my father showed me a compass. That this needle behaved in such a determined way did not at all fit into the nature of those events which could find a place in the world of concepts (effects connected with direct 'touch'). I can still remember – or at least believe I can remember – that this experience made a deep and lasting impression on me. Something deeply hidden had to be behind such things. What man sees before him from infancy does not cause any reaction of this kind; he s not surprised by the falling of bodies, by the wind and rain, nor by the moon or the fact that the moon does not fall down, or by the differences between living and non-living matter.

At the age of 12 I experienced a second wonder of a totally different nature, in a little book dealing with Euclidean plane geometry, which came into my hands at the beginning of a schoolyear. Here were assertions, such as, eg., that of the intersection of the 3 altitudes of a triangle at a single point, which – though by no means evident – could be proved with such certainty that any doubt seemed to be out of the question. This lucidity and certainty made an indescribable impression on me. That the axiom had to be accepted unproved did not disturb me. In any case it was quite sufficient for me if I could peg proofs on propositions whose validity did not seem to be in doubt......Only things which did not seem to be similarly self-evident seemed to me to be in need of any proof at all. In addition, the objects of which geometry deals seemed to me to be no different in type from the objects of sensory perception, 'which can be seen and touched'. This primitive idea, which I think probably also lies at the bottom of the well-known Kantian query concerning the possibility of 'a priori *synthetic judgements', obviously rests upon the fact that the relation of geometric concepts to objects of direct experience (rigid rods, finite time intervals, etc.) was unconsciously present.*

Even if it thus seemed that it was possible to acquire certain knowledge of the objects of experience by means of pure thinking, nevertheless this 'wonder' rested upon an error. However, for anyone experiencing it for the first time, it seems quite marvelous that man is capable at all of reaching such a degree of certainty and purity in thinking as that which the Greeks showed us for the first time to be possible in geometry...

...Let me not hesitate to state here my epistemological credo, although in the foregoing, something has already been said incidentally about this. This credo actually only evolved much later, and very slowly, and does not correspond with the point of view I held in my younger years.

I see on the one hand the totality of sense experiences, and on the other hand, the totality of the concepts and propositions which are laid down in books. The relations between the concepts and propositions, amongst themselves and with each other, are of a strictly logical kind, and the business of logical thinking is strictly limited to the achievement of the connections between concepts and propositions, according to firmly laid down rules, which are themselves the concern of logic. Now the concepts and propositions acquire 'meaning' ie., 'content, only through their connection with sense-experiences. The connection of the latter with the former is purely intuitive, not of a logical nature. Only the degree of certainty with which this intuitive connection can be established, and nothing else, is what differentiates empty fantasy from scientific 'truth'. The set of concepts is a creation of man, along with the the rules of syntax, which together constitute the the structure of the conceptual system. Although such conceptual systems are logically entirely arbitrary, they aim, first, to attain the most certain (intuitive) and complete coordination that is possible, with the totality of sense-experiences; and second, they aim at the greatest possible economy of their logically independent elements (basic concepts and axioms), ie., of their undefined concepts and underived [postulated] propositions.

A proposition is correct if, within a logical system, it is deduced according to the accepted logical rules. A system has truth-content according to how complete and certain is the possibility of coordinating it with the totality of experience. A correct proposition then burrows its 'truth' from the truth content of the system to which it belongs.

A remark as to the historical development. 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, ie., 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.*

Einstein, in Schilpp, LLP, "Autobiographical Notes", p. 13 (1949)

A number of comments here are in order. First, as we have already seen, Einstein simply did not accept the idea, which is unquestioned in most of Western philosophy since Socrates and Plato, that all thought is in the form of words or some more general set of signs. Since most philosophers in the West assume that all philosophical debate must be conducted in the form of arguments phrased in words, this indicates a huge gap between Einstein and most conventional philosophical discussion. It might be argued that even if Einstein is right, nevertheless any coherent understanding of reality, or any kind of communicable analysis of it, can only involve language. However he would certainly have denied this. We see this from his discussion of how the feeling of 'wonder' arises in ways which we can hardly understand – in many ways unconscious – and reacts back decisively on our 'thought world'. The two are inextricably connected, and the underlying mental processes are, for Einstein, beyond words or signs. And yet these conscious or unconscious processes are, in his opinion, decisive in the way they affect our thinking. It is clearly implied in what he says that one must have very important non-verbal communication between people (other people are, after all, just another part of the experience of any individual, and thereby can equally incite strong non-verbal feelings such as wonder). The obvious question that one can ask is why had this (rather obvious) fact been ignored in most philosophical discussions up to that time (and in most discussions since!).

The enormous importance of this non-verbal thinking to Einstein is often repeated by him. In the passage just quoted we see how it plays a key role in arousing wonder, and in the formation of new ideas, which one formulates in a 'free play of the mind'. This free play not only functions at the level of concepts and language (and we will discuss the crucial importance of this below), but also and just as importantly, well below this level, in an entirely non-verbal and even subconscious realm.

A second comment on the examples Einstein gives of this 'arousal of wonder' are historically of great importance. We see that when only 4-5 years old his sense of wonder was aroused by his first experience of what Faraday and Maxwell had formulated as the concept of a 'field': indeed, Einstein was witnessing the action of a static magnetic field on a magnetized solid. His explanation of the sense of wonder is that at a largely subconscious level, this clashed with deep intuitive preconceptions he had - which were non-verbal. The resolution of this clash also had to proceed at a non-verbal level. It goes without saying that this resolution was of great historical importance - it ultimately played an important role in the genesis of the special and general theories of relativity. Just as important a role was played by geometry, and so his second example is equally interesting. Again, his reaction to Euclidean geometry consisted in a non-verbal and non-symbolic sense of wonder – not so much at the symbolic mathematical formulation of this, so much as the realization that there existed *a priori* ideas. Many people over the centuries have experienced very strong emotions at their first experience of Euclid (often quite dissimilar to those of Einstein!). But again, the crucial point here is that this reaction is well below the verbal/symbolic level, and doubtless involves unconscious elements underlying the conscious feelings that are experienced.

There is no doubt at how important a role was played in the development of Einstein's ideas by such mental processes, and he stressed even when in his last years how important it was for people to maintain their curiosity and sense of child-like wonder at the world – for him, as we saw above, this was the only way to attain the path to real understanding, largely lost by most adults. Indeed, for Einstein, this loss – this 'flight from wonder' – even though it leads to a greater sophistication in the 'thought world' of signs, language, and symbolic concepts, nevertheless also leads to an erosion of the deep understanding stimulated by wonder. Thus for him there was a deep incompatibility between intuitive understanding and formal thought. Needless to say, such an idea is deeply antagonistic to much of rationalistic Western philosophy. Moreover, in the hands of most thinkers who have ventured into such terrain, such ideas have led to various strongly irrational (and sometimes totalitarian) philosophical dogmas. But Einstein was utterly opposed to any such irrational or mystical tendencies, and was unyieldingly rationalist in his outlook, as we have seen.

This makes his stated epistemological credo even more interesting. The passage quoted above frames this in terms of the highly formal thinking involved in physics, mathematics, and logic. As stated, there seems at first to be nothing very controversial about what he says - mathematical and logical systems are created by a free play of the mind, and only acquire meaning through their association or 'coordination' with the objects of experience. Whether the formal system applies to experience can only be checked by empirical investigation. This idea, as stated, is certainly in accord with the views of almost all working scientists at the present time – it seems to be a nice simple description of the dialogue that goes on, between theory and experiment, in any empirical science.

A little reflection shows, however, that there are several problems here. First, how is the connection or 'coordination' made between intuitive, sometimes unconscious ideas and the formal objects of mathematics? Einstein states this can only be done intuitively, but how? And second, what 'objects' in our experience are we talking about here? These questions raise well-known and rather severe problems, which were of course partially addressed by Kant and Hume. Let us see how Einstein, now in a more philosophical vein, addressed them:

On the stage of our subconscious mind appear in colorful succession sense experiences, memory pictures of them, representations and feelings. In contrast to psychology, physics treats directly only of sense experiences and of the "understanding" of their connection. But even the concept of the "real external world" of everyday thinking rests exclusively on sense impressions.

Now we must first remark that the differentiation between sense impressions and representations is not possible; or, at least it is not possible with absolute certainty. With the discussion of this problem, which affects also the notion of reality, we will not concern ourselves but we shall take the existence of sense experiences as given, that is to say, as psychic experiences of a special kind.

I believe that the first step in the setting of a "real external world" is the formation of the concept of bodily objects and of bodily objects of various kinds. Out of the multitude of our sense experiences we take, mentally and arbitrarily, certain repeatedly occurring complexes of sense impression (partly in conjunction with sense impressions which are interpreted as signs for sense experiences of others), and we attribute to them a meaning-the meaning of the bodily object. Considered logically this concept is not identical with the totality of sense impressions referred to; but it is an arbitrary creation of the human (or animal) mind. On the other hand, the concept owes its meaning and its justification exclusively to the totality of the sense impressions which we associate with it.

The second step is to be found in the fact that, in our thinking (which determines our expectation), we attribute to this concept of the bodily object a significance, which is to a high degree independent of the sense impression which originally gives rise to it. This is what we mean when we attribute to the bodily object "a real existence." The justification of such a setting rests exclusively on the fact that, by means of such concepts and mental relations between them, we are able to orient ourselves in the labyrinth of sense impressions. These notions and relations, although free statements of our thoughts, appear to us as stronger and more unalterable than the individual sense experience itself, the character of which as anything other than the result of an illusion or hallucination is never completely guaranteed. On the other hand, these concepts and relations, and indeed the setting of real objects and, generally speaking, the existence of "the real world," have justification only in so far as they are connected with sense impressions between which they form a mental connection.

The very fact that the totality of our sense experiences is such that by means of thinking (operations with concepts, and the creation and use of definite functional relations between them, and the coordination of sense experiences to these concepts) it can be put in order, this fact is one which leaves us in awe, but which we shall never understand. One may say "the eternal mystery of the world is its comprehensibility." It is one of the great realizations of Immanuel Kant that the setting up of a real external world would be senseless without this comprehensibility.

In speaking here concerning "comprehensibility," the expression is used in its most modest sense. It implies: the production of some sort of order among sense impressions, this order being produced by the creation of general concepts, relations between these concepts, and by relations between the concepts and sense experience, these relations being determined in any possible manner. It is in this sense that the world of our sense experiences is comprehensible. The fact that it is comprehensible is a miracle.

In my opinion, nothing can be said concerning the manner in which the concepts are to be made and connected, and how we are to coordinate them to the experiences. In guiding us in the creation of such an order of sense experiences, success in the result is alone the determining factor. All that is necessary is the statement of 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 (i.e. there are no final categories in the sense of Kant).

The connection of the elementary concepts of everyday thinking with complexes of sense experiences can only be comprehended intuitively and it is unadaptable to scientifically logical fixation. The totality of these connections – none of which is expressible in notional terms – is the only thing which differentiates the great building which is science from a logical but empty scheme of concepts. By means of these connections, the purely notional theorems of science become statements about complexes of sense experiences.

We shall call "primary concepts" such concepts as are directly and intuitively connected with typical complexes of sense experiences. All other notions are – from the physical point of view – possessed of meaning, only in so far as they are connected, by theorems, with the primary notions. Some of these theorems are definitions of the concepts (and of the statements derived logically from them), and some are not derivable from the definitions, and express at least indirect relations between the "primary concepts," and in this way between sense experiences. Theorems of the latter kind are "statements about reality" or laws of nature, i.e. theorems which have to show their usefulness when applied to sense experiences comprehended by primary concepts. The question as to which of the theorems shall *be considered as definitions and which as natural laws will depend largely upon the chosen representation. It really becomes absolutely necessary to make this differentiation only when one examines the degree to which the whole system of concepts considered is not empty from the physical point of view.*

from "Physics and Reality" by Albert Einstein, J. Franklin Inst. **221**, 349-382 (1936)

Let us first look at how Einstein answers the question of how the correspondence is formed between our non-verbal intuitions of the world and our formal thinking. His answer is framed in Kantian terms. We have sense impressions, etc., and 'representations'; but the first state in the link to rational thinking is made by the concept of an 'object'; and more particularly a physical object. Again, this is not yet formalized in any way - it is non-verbal, and intuitive. The idea that the metaphysical notion of 'object', in the most general sense, is fundamental to thought, comes directly from Kant. Einstein is simply saying that the whole notion of an 'external world' requires physical objects as a fundamental intuitive notion.

The next key step is to attribute to such physical objects the status of being 'Real', so that all subsequent more formal ideas about these objects are then supposed to refer to what, elsewhere, Einstein referred to as 'elements of reality'. However, all such further reasoning, as well as the initial association of these objects with the 'real world', must be regarded as a free play of the mind, whether this play be rational and symbolic, or intuitive and non-symbolic. The fact that one can do any of this was where, for Einstein, the great and miraculous mystery lay. His answer to the question of why the world appears to be ordered rationally was simply that he did not know - it simply was, as far as we could tell, and that is a miracle. His reason for believing that the world was rational was not really very different from that of Kant - if it were not the case, then nothing would be comprehensible, and thinking as we know it would be impossible.

Has Einstein, in this formulation, evaded the apparent contradiction between faith in reason (which for him was the same as 'faith in a rational universe'), and rationality itself, that was discussed above? Recall that the contradiction arises because a faith in reason implies that rationality is certainly justified, but that according to Humean arguments, reason denies the certain truth of any faith. It seems however that Einstein's view can be summarized as follows: the mere existence of *thinking* (including, as one possible element of it, the development of a 'faith' in both the idea of 'reality', and the objects of reality) necessarily implies a rational universe; and since thinking does exist, the universe must be rational, thereby justifying rational thinking for certain. The flaw in this argument is that one can, if one wishes, argue that the universe only seems to be rational - there is nothing to say that things may be going on which are or will render it irrational, of which we are unaware (but may become aware of tomorrow, at least just as we lose our capacity to think!). This is just Hume's inductive argument all over again.

The role of this sequence of arguments in Einstein's epistemology is so important that it is worth hearing about it again in a different form, which now also addresses the biggest problem that Einstein confronted in the elaboration of his epistemological credo. This was of course quantum mechanics. Here Einstein addresses directly the question of what he means by physical reality:

A few more remarks of a general nature concerning concepts and [also] concerning the insinuation that a concept - for example that of the Real - is something metaphysical (and therefore to be rejected). A basic conceptual distinction, which is a necessary prerequisite of scientific and pre-scientific thinking, is the distinction between sense-impressions (and the recollection of such) on the one hand and mere ideas on the other. There is no such thing as a conceptual definition of this distinction (aside from, circular definitions, i.e., of such as make a hidden use of the object to be defined). Nor can it be maintained that at the base of this distinction there is a type of evidence, such as underlies, for example, the distinction between red and blue. Yet, one needs this distinction in order to be able to overcome solipsism. Solution: we shall make use of this distinction unconcerned with the reproach that, in doing so, we are guilty of the metaphysical original sin. We regard the distinction as a category which we use in order that we might the better find our way in the world of immediate sensations. The sense and the justification of this distinction lies simply in this achievement. But this is only a first step. We represent the sense-impressions as conditioned by an objective and by a subjective factor. For this conceptual distinction there also is no logical-philosophical justification. But if we reject it, we cannot escape solipsism. It is also the presupposition of every kind of physical thinking. Here too, the only justification lies in its usefulness. We are here concerned with categories or schemes of thought, the selection of which is, in principle, entirely open to us and whose qualification can only be judged by the degree to which its use contributes to making the totality of the contents of consciousness intelligible. The above mentioned objective factor is the totality of such concepts and conceptual relations as are thought of as independent of experience, viz., of perceptions. So long as we move within the thus programmatically fixed sphere of thought we are thinking physically. Insofar as physical thinking justifies itself, in the more than once indicated sense, by its ability to grasp experiences intellectually, we regard it as knowledge of the real.

After what has been said, the Real in physics is to be taken as a type of program, to which we are, however, not forced to cling a priori. *No one is likely to be inclined to attempt to give up this program within the realm of the macroscopic* *(location of the mark on the paper strip real). But the macroscopic and the microscopic are so inter-related that it appears impracticable to give up this program in the microscopic alone. Nor can I see any occasion anywhere within the observable facts of the quantum field for doing so, unless, indeed, one clings a priori to the thesis that the description of nature by the statistical scheme of quantum mechanics is final.*

The theoretical attitude here advocated is distinct from that of Kant only by the fact that we do not conceive of the categories as unalterable (conditioned by the nature of the understanding) but as (in the logical sense) free conventions. They appear to be a priori *only insofar as thinking without the positing of categories and of concepts in general would be as impossible as is breathing in a vacuum.*

From these meagre remarks one will see that to me it must seem a mistake to permit theoretical description to be directly dependent upon acts of empirical assertions, as it seems to me to be intended [for example] in Bohr's principle of complementarity, the sharp formulation of which, moreover, I have been unable to achieve despite much effort which I have expended on it. From my point of view [such] statements or measurements can occur only as special instances, viz., parts, of physical description, to which I cannot ascribe any exceptional position above the rest.

Einstein, in Schilpp, LLP, "reply to criticisms", p. 673 (1949)

We will look again at how Einstein understood Physical Reality in section 2.3 below, where we discuss all this from the point of view of his work in physics. However we may now summarize Einstein's purely philosophical position as follows. We have already seen that he was fully conscious that we cannot ever know, as humans, anything but some tiny aspect of the 'cosmic truth', ie., truth about 'the Real'. Hence his remark that our feeble attempts to grasp at reality must always be understood as a programme, in which we would only ever have limited success. Moreover, the concept of the Real itself is not given *a priori*; as we have just seen, it was for him something that was introduced by our minds at a primitive intuitive level.

On the other hand he did not see any good reason, at a practical level, to give it up, given its remarkable success. Indeed, in a way which is certainly consistent with the Kantian line, he felt that the whole idea of 'objects' was so fundamental to human cognition, and to the idea of "Reality", that it would have been literally unthinkable to give up this fundamental mode of thinking. The only difference here with Kant, which he makes explicit at this point, is that the categories that one subsequently uses to give structure to objects and to reality are not given *a priori*, but subject to a free play of the mind (ie., "mental experimentation").

Thus we may say, roughly, that Einstein was prepared to give up almost any strictures on what the various Kantian categories should be. However, it turns out that there was a point past which he was not willing to go, in allowing such a 'free play of the mind'. That is, he was not prepared to give up the more fundamental notion of 'object', in any discussion of Reality - not because he felt that this conception was necessarily true of Reality, but that no discussion of Reality was possible without it.

However it is also clear that when it came to the philosophical crunch, what was really important for Einstein was not the abstract set of objects which make up the 'noumena', the 'things on themselves' that populate Kant's unknowable Real World. Einstein rightly felt that since the Real world is unknown to us, and indeed forever beyond our possibly understanding or perception, then we are ultimately quite unjustified in attempting to force even such a primitive conception as 'object' on it, in order to give it some structure - even though it is not even possible to talk or even think about Reality without doing so. On the other hand when it came to the discussion of the physical world, the world of 'Physical Reality', he was much less flexible. Indeed, he did not want to give up the idea of a 'physical object', ie., an object in the physical world - which for him, had to be localized in spacetime. Thus, for Einstein, the notion of 'Reality' ultimately boiled down to 'Physical Reality', at least insofar as Reality is accessible to humans; and for him, Physical Reality necessarily involved local objects.

Thus, in discussing Einstein's philosophical credo - which as we have seen was an interesting blend of a metaphysics and an epistemology both strongly influenced by his reading of Hume and Kant, along with a heavy dose of faith in a kind of 'cosmic order' - we are inevitably led to his views on Physical Reality. These latter views form the third major foundation upon which his philosophical views rested.

2.3 PHYSICAL REALITY: SPACETIME, FIELDS, and QUANTUM MATTER

It is obvious that Einstein's philosophical views changed in response to the discoveries he made, along with the other influences discussed above. But what were the key elements here, how did they arise, and how did they fit together into his final point of view?

To answer this, let us first very briefly recall the main features of Einstein's work that are relevant to this question (these are discussed in much more detail in the Notes on Einstein's work - here we are only concerned with the philosophical side of this). The first key part of this is contained his work on relativity. As we have seen, Einstein's special theory arose very much from his desire to reconcile the electromagnetic field equations of Maxwell with Newtonian mechanics. Einstein had enormous respect for both thinkers and their achievements, and they both had a major role in influencing his thinking, as he made amply clear. On the topic of Newton and Newtonian theory, for example:

"*Newton's fundamental principles were so satisfactory from the logical point of view that the impetus to overhaul them could only spring from the demands of empirical fact. Before I go into this, I must emphasize that Newton himself was better aware of the weaknesses inherent in his intellectual edifice than the generations of learned scientists which followed him. This fact has always aroused my deep admiration, and I should like, therefore, to dwell on it for a moment.*

I. Newton's endeavours to represent his system as necessarily conditioned by experience and to introduce the smallest possible number of concepts not directly referrable to to empirical objects is everywhere evident; in spite of this he set up the concepts of absolute space and absolute time. For this he has often been criticized in recent years. But in this point Newton is particularly consistent. He had realized that observable geometrical quantities (distances of material points from one another) and their course in time do not completely characterize motion in its physical aspects. He proved this in the famous experiment with the rotating vessel of water. Therefore, in addition to masses and temporally variable distances, there must be something else that determines motion. That 'something' he takes to be the relation to 'absolute space'. He is aware that space must possess a kind of physical reality if his laws of motion are to have any meaning, a reality of the same sort as material points and their distances.

The clear realization of this reveals both Newton's wisdom and also a weak side to his theory. For the logical structure of the latter would undoubtedly be more satisfactory without this shadowy concept; in that case only things whose relations to perception are perfectly clear (mass points, distances) would enter into his laws.

II. Forces acting directly and instantaneously at a distance, as introduced to represent the effects of gravity, are not in character with most of the processes familiar to us from everyday life. Newton meets this objection by pointing to the fact that his law of gravitational interaction is not supposed to be a final explanation, but a rule derived by induction from experience.

III. Newton's theory provided no explanation for the highly remarkable fact that the weight and inertia of a body are determined by the same quantity (its mass). Newton himself was aware of the peculiarity of this fact. "

from A Einstein, *Naturwissenschaften* **15**, 273 (1927)

Einstein's feelings about Maxwell's ideas were interesting. On the one hand there was undiluted admiration for the idea of the field, as adumbrated by Faraday and completed by Maxwell. There is no question that the concept of the field, and its formulation in terms of partial differential equations, was for Einstein the single most important cornerstone of theoretical physics. He had this to say about it:

"*In order to put his system into mathematical form at all, Newton had to devise the concept of differential quotients and formulate the laws of motion as total differential equations – perhaps the single greatest advance in thought that a single individual was ever privileged to make. Partial differential equations were not necessary for this purpose, nor did Newton make any systematic use of them. But they were necessary for the formulation of the mechanics of deformable bodies: this is connected with the fact that that in these problems, the question of* how *bodies are supposed to be constructed from material points was of no importance.*

Thus the partial differential equation entered physics as a handmaid, but has gradually become mistress. This began in the 19th century, when he wave theory of light established itself under the pressure of observed fact. Light in empty space was explained as a matter of vibrations of the ether, and it seemed superfluous at that stage to look upon the latter as a conglomeration of material points. Here for the first time the the partial differential equations appeared as the natural expression of the primary realities of physics. In one particular area of theoretical physics the continuous field thus appeared side by side with the material point, as the the representative of physical reality. This dualism remains even today, disturbing as it must be to every orderly mind.

If the idea of physical reality had ceased to be purely atomic, it still remained for the time being purely mechanistic: *people still tried to explain all events as the motion of inert masses, and indeed no other way of looking at things seemed possible. Then came the great change, which will forever be associated with the names of Faraday, Maxwell, and Hertz. The lion's share in this revolution fell to Maxwell. He showed that the whole of what was then known about light and electromagnetic phenomena was expressed in his well-known double system of differential equations, in which the electric and magnetic fields appear as the dependent variables. Maxwell did, nevertheless, try to explain or justify these equations by the intellectual construction of a mechanical model.*

However he made use of several such constructions at the same time, and took none of them really seriously, so that the equations alone appeared as the essential thing, and the field strengths as the ultimate entities, not to be reduced to anything else. By the turn of the century the concept of the electromagnetic field as an ultimate physical entity had been generally accepted, and serious thinkers had abandoned the belief in either the justification or the possibility of a mechanical explanation of Maxwell's equations. Before long they were, on the contrary, instead trying to explain *material point and their inertia on field theory lines, with the help of Maxwell's theory – an attempt which did not, however, meet with complete success.*

Neglecting the important individual *results that Maxwell's life-work produced in important areas of physics, and concentrating on the changes wrought by him in our conception of physical reality, we may say this: before Maxwell, people conceived of physical reality – insofar as it is supposed to represent events in Nature – as material points, whose changes consist exclusively of motions, which are subject to total differential equations. After Maxwell they understood physical reality as represented by continuous fields, not mechanically explicable, which are subject to partial differential equations.*

From A Einstein, "*Maxwell's influence on the evolution of the idea of physical reality*",
from the book "*James Clerk Maxwell: a commemoration volume*" (C.U.P., 1931).

On the other hand he felt that the field revolution had not been completed properly, and this for him was always the biggest problem facing physics. Let us continue directly on from the passage above, to see what he felt were the problems. first, the problems that were involved in his own theory:

"*This change in our conception of physical reality is the most profound and fruitful one to have emerged in physics since Newton – but it has to be admitted at the same time that it has by no means been completely carried out. The successful systems in physics of physics which have evolved since then represent rather compromises between these two schemes, which for that reason bear a provisional and logically incomplete character, although they have achieved great advances in certain particulars.*

The first of these that calls for mention is Lorentz's theory of electrons, in which the field and electrical corpuscles appear side by side as elements of equal value for the comprehension of reality. Next come the special and general theories of relativity, which although they are based entirely on field-theoretical ideas, have so far been unable to avoid the independent introduction of material points and total differential equations.

From A Einstein, "*Maxwell's influence on the evolution of the idea of physical reality*",
from the book "*James Clerk Maxwell: a commemoration volume*" (C.U.P., 1931).

It is worth pausing her to consider in a little more detail how Einstein looked at the General Theory of Relativity, and the way in which its mathematical structure reflected the field-theoretical viewpoint. It is well-known that Einstein did not initially realize that he was being led by his own theory to a view of spacetime as a field in itself. Like all those before him, he initially thought of it as a kind of 'receptacle' for matter and events, in the way laid down by Newton. But once he had realized that this was not the case, and that the spacetime must itself be a field, capable of supporting waves, and carrying its own stress-energy, he was very satisfied with this aspect of the theory. Indeed, he spent a great deal of time in the 1930's, with Infeld and other collaborators, elaborating the rather subtle theory of gravitational waves, as well as exploring the possible structures of spacetime that could be found (including the famous 'Einstein-Rosen bridge' solution, now known as the 'wormhole' solution). This then led him to some very important reflections on the whole theory of gravitation, as a new kind of field theory. First, on the new structure of spacetime, which had lost its previous 'flat receptacle' status:

"*From this [the principle of equivalence] it follows that there is no longer any reason for favoring, as a fundamental principle, the "inertial systems"; and, we must admit as equivalent in their own right, also non-linear transformations of the coordinates (x_l, x_2, x_3, x_4). If we make such a transformation of a system of coordinates of the special theory of relativity, then the metric*

$$ds^2 = dx_1^2 + dx_2^2 + dx_3^2 - dx_4^2 \tag{0.1}$$

goes over to a general (Riemannian) metric of form

$$ds^2 = \sum_{\mu,\nu} g_{\mu\nu} dx_\mu dx_\nu \tag{0.2}$$

where the $g_{\mu\nu}$, symmetrical in μ and ν, are certain functions of $x_1 ... x_4$ which describe both the metric property, and the.gravitational field in relation to the new system of coordinates.

The foregoing improvement in the interpretation of the mechanical basis must, however, be paid for in that-as becomes evident on closer scrutiny – the new coordinates could no longer be interpreted, as results of measurements by rigid bodies and clocks, as they could in the original system (an inertial system with vanishing gravitational field).

The passage to the general theory of relativity is realized by the assumption that such a representation of the field properties of space already mentioned, by functions $g_{\mu\nu}$ (that is to say by a Riemann metric), is also justified in the *general case in which there is no system of coordinates in relation to which the metric takes the simple quasi-Euclidian form of the special theory of relativity.*

Now the coordinates, by themselves, no longer express metric relations, but only the "neighborliness" of the things described, whose coordinates differ but little from one another. All transformations of the coordinates have to be admitted so long as these transformations are free from singularities. Only such equations as are covariant in relation to arbitrary transformations in this sense have meaning as expressions of general laws of nature (postulate of general covariance)."

from A Einstein, "Physics and Reality", J. Franklin Inst. **221**, 349-382 (1936)

The picture given here of the ontological status of the spacetime metric, and of the spacetime field, has more or less survived since the time that Einstein wrote these words. However he himself was not happy with it, even at that time. There were two main reasons for this. The first concerned the spacetime field itself, and the properties of it that began to emerge from the theory once theoretical physicists began to explore its properties. Disturbing features began to show themselves almost immediately. First was the appearance of 'singular solutions to the field equations. He fought against these from the very beginning, starting from his introduction of the cosmological term to suppress the 'Big Bang' singularity, and continuing in his later rejection of 'black hole' singularities within the existing universe. The 'expanding universe' solution was found only months after the publication of the General Relativistic field equations in their final form. Einstein's 'cosmological term', which he then introduced into the equations, was designed to suppress this solution - the subsequent history of this term is discussed in the Notes on Relativity. Then in the 1930's came the the discovery of both singular solutions to the equations (including what are now called 'black holes'), and of 'Einstein-Rosen bridges' between different regions of spacetime (what are now called 'wormholes'). Einstein simply could not accept singular solutions - he felt that no field theory was decent with them, and that they had to be suppressed. This attitude meant that the original 1938 work of Oppenheimer, Volkoff, and Snyder, which first discussed such the origin of black hole singularities in stellar collapse, was largely ignored until after Einstein's death. Einstein would have been profoundly disturbed to learn of the subsequent development of this work. First, in the 1950's, the Russian school (EM Lifshitz, IM Khalatnikov, and collaborators) described the form of singular solutions to the field equations in great detail (with later work by Kerr completing the picture); and then Penrose in the early 1960's showed that such singularities were not only generic to the theory, but in fact mathematically inevitable. In the last two decades the enormous astrophysical importance of these singular solutions has becomes apparent in observations, notably of supermassive black holes in galactic centres (including quasars), and in our deciphering of events in the early universe.

Since Einstein did not live to see these developments come to fruition, one can only guess at whether he would or would not have changed his view that a proper field theory should not admit singularities. The overwhelming evidence that singularities do exist suggests that he would have simply had to live with them, in the same way that he had to live with singular solutions of Maxwell's equations around a point charge. But it seems doubtful that he would have unequivocally accepted this feature of the theory.

It is less obvious how he might have reacted to the later history of the Einstein-Rosen bridge. The fundamental work of Kerr in 1964 showed that such wormhole solutions were also inevitable - they were nothing but rotating black holes. The question of how rotational or 'twist' solutions came out of the equations was also a topic of continuing interest to Einstein. For his it was initially linked to the question raised by E Mach, viz., to what extent the inertial properties of matter were governed by the distribution of matter in the universe. The early Lense-Thirring solution of the field equations around a rotating body showed that rotating matter could generate a torsion in the spacetime metric, which would cause a freely-falling gyroscope to precess.

But none of this apparently prepared Einstein for Gödel's 1944 solution of a *rotating universe*, in which no matter was required to generate the torsion, and in which moreover, closed time loops existed. This raised profound questions, which Einstein later addressed as follows:

"*The problem here involved disturbed me already at the time of the building up of the general theory of relativity, without my having succeeded in clarifying it. Entirely aside from the relation of the theory of relativity to idealistic philosophy or to any philosophical formulation of questions, the problem presents itself as follows:*

If P is a world-point, a light-cone ($ds^2 = 0$) belongs to it. We draw a time-like world-line through P and on this line observe the close world-points B and A, separated by P. Does it make any sense to provide the world-line with an arrow, and to assert that B is before P, A after P?

Is what remains of temporal connection between world-points in the theory of relativity an asymmetrical relation, or would one be just as much justified, from the physical point of view, to indicate the arrow in the opposite direction and to assert that A is before P, B after P?

In the first instance the alternative is decided in the negative, if we are justified in saying: If it is possible to send (to telegraph) a signal (also passing by in the close proximity of P) from B to A, but not from A to B, then the one-sided

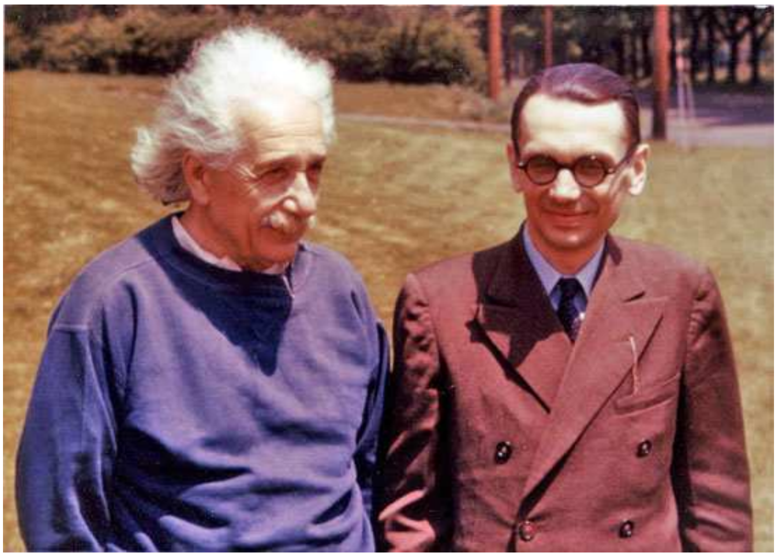

FIG. 4: A Einstein and K Gödel in Princeton in the late 1940s. It is interesting to ask what resulted from the acquaintance of the two greatest scientists of the 20th century. Gödel took some interest in Einstein's theory of relativity, but Einstein apparently had nothing of any originality to say about Gödel's famous work on the completeness and consistency of formal systems.

(asymmetrical) character of time is secured, i.e., there exists no free choice for the direction of the arrow. What is essential in this is the fact that the sending of a signal is, in the sense of thermodynamics, an irreversible process, a process which is connected with the growth of entropy (whereas, according to our present knowledge, all elementary processes are reversible).

If, therefore, B and A are two, sufficiently neighbouring, world-points, which can be connected by a time-like line, then the assertion: "B is before A", makes physical sense. But does this assertion still make sense, if the points, which are connectable by the time-like line, are arbitrarily far separated from each other? Certainly not, if there exist point-series connectable by time-like lines in such a way that each point precedes temporally the preceding one, and if the series is closed in itself. In that case the distinction earlier-later is abandoned for world-points which lie far apart in a cosmological sense, and those paradoxes, regarding the direction of the causal connection, arise, of which Mr. Gödel has spoken.

Such cosmological solutions of the gravitation-equations (with not vanishing A-constant) have been found by Mr. Gödel. It will be interesting to weigh whether these are not to be excluded on physical grounds."

from A Einstein, "reply to criticisms", LLP (1949)

Again, one wonders at how Einstein would have reacted to the subsequent clarification of this topic by Kerr, and to the continuing discussions of the well-known paradoxes raised in physics by the existence of closed time loops (such as the 'grandfather paradox'). One suspects that he would have rejected all of this in favour of some alternative treatment of singular solutions, or a modification of the theory to deal with them.

We see from all this that even the field equations themselves, in the absence of any detailed consideration of the matter in them, led to severe conceptual problems. One could of course leave it at this, and refrain from going on to discuss how to deal in more detail with the matter which contributes to the stress-energy tensor in the theory. However, Einstein was not satisfied with this. The problem lay in the form of the final equations of General Relativity, in which both those terms describing the gravitational field and its curvature appear, and also the terms describing matter. These two are related by the general field equation (described by the famous remark that 'space tells matter how to move, and matter tells space how to curve'). But they do not appear in the same way:

"*One sets up a field equation*

$$R_{ik} - \frac{1}{2} g_{ik} R = -T_{ik} \tag{0.3}$$

where R represents the scalar of Riemannian curvature, and T_{ik} is the energy tensor of the matter in a phenomenological representation. The left side of the equation is chosen in such a manner that its divergence disappears identically. The resulting disappearance of the divergence of the right side produces the "equations of motion" of matter, in the form of partial differential equations for the case where T_{ik} introduces, for the description of the matter, only four *further functions independent of each other (for instance, density, pressure, and velocity components, where there is between the latter an identity, and between pressure and density an equation of condition).*

By this formulation one reduces the whole mechanics of gravitation to the solution of a single system of covariant partial differential equations. The theory avoids all internal discrepancies which we have charged against the basis of classical mechanics. It is sufficient-as far as we know-for the representation of the observed facts of celestial mechanics. But, it is similar to a building, one wing of which is made of fine marble (left part of the equation), but the other wing of which is built of low grade wood (right side of equation). The phenomenological representation of matter is, in fact, only a crude substitute for a representation which would correspond to all known properties of matter."

from A Einstein, "Physics and Reality", J. Franklin Inst. **221**, 349-382 (1936)

The problem is that the left hand-side of this famous equation describes spacetime and its curvature, but the right-hand side, written in terms of the stress-energy tensor, also contains contributions from matter (which of course also possesses energy and therefore causes spacetime curvature). Now from the point of view of electromagnetic field theory, as conceived by Maxwell and later elaborated by Lorentz, this is quite natural - it is the stress-energy 'source' term on the right-hand side which drives the time evolution of the spacetime metric, in the same way that the charges in electromagnetic theory are responsible for causing disturbances of the electromagnetic field. The stress-energy is nothing but the 'charge' in this equation. However, quite apart from any problems Einstein had with the theory of matter then prevailing (to which we come below), Einstein still didn't like this - he felt that it was a fundamental defect of field theory itself:

"*For the construction of the present theory of relativity the following is essential:*

(1) Physical things are described by continuous functions, field-variables of four co-ordinates. As long as the topological connection is preserved, these latter can be freely chosen.

(2) The field-variables are tensor-components; among the tensors is a symmetrical tensor g_{ik} *for the description of the gravitational field.*

(3) There are physical objects, which (in the macroscopic field) measure the invariant ds.

If (1) and (2) are accepted, (3) is plausible, but not necessary. The construction of the mathematical theory rests exclusively upon (1) and (2).

A complete theory of physics as a totality, in accordance with (1) and (2) does not yet exist. If it did exist, there would be no room for the supposition (3). For the objects used as tools for measurement do not lead an independent existence alongside of the objects implicated by the field equations. It is not necessary that one should permit one's cosmological considerations to be restrained by such a sceptical attitude; but neither should one close one's mind towards them from the very beginning."

Einstein, in Schilpp, LLP, "reply to criticisms", p. 684 (1949)

In other words, Einstein felt that it was a *good thing* that General Relativity had divested itself of the clocks and rods of special relativity, these 'tools for measurement'; and it was then not acceptable that they should then appear again in the theory, as material objects, on a different footing from the spacetime field. What he wanted was a theory in which the matter appeared on the same footing as the spacetime, as a feature of a field in itself - in other words, he wanted a unified field theory.

Einstein was certainly being logically consistent here to reject the introduction of matter as an external ingredient in the equations. But he had other reasons for doing this apart from logical consistency. The first was that the introduction of point particles inevitably introduced singularities into the spacetime matric; as noted above, these were first discussed already in 1938-39, in papers by Oppenheimer and Volkoff and Oppenheimer and Snyder, and Einstein fundamentally rejected such singularities. The second reason that Einstein had, for rejecting the structure of General Relativity as provisional, was contained in his misgivings about the theory of matter that was at that time showing unprecedented success. Both of these reasons show up in his essay on Maxwell; let us then return to this, to see how he completes his survey of physics up to that time:

The last and most successful creation of theoretical physics, namely, quantum mechanics, differs fundamentally from both previous schemes, which we will for brevity's sake call the 'Newtonian' and 'Maxwellian' schemes. The quantities figuring in quantum mechanics make no claim to represent physical reality, but only the probabilities of occurrence of the physical reality that we have in mind. Dirac, to whom in my opinion we owe the most perfect logical exposition of this theory, rightly points out that it would be difficult, for example, to give a theoretical description of a photon sufficient to decide whether or not it will pass a polarizer placed (obliquely) in its path.

I am still inclined to believe that physicists will not, in the long run, content themselves with this sort of indirect description of the real, even if the theory can eventually be adapted to to the postulate of general relativity in a *successful manner. We shall then, I feel sure, have to return to the attempt to carry out the programme which may be properly described as the Maxwellian one – namely, the description of physical reality by fields which satisfy partial differential equations without singularities.*

From A Einstein, "*Maxwell's influence on the evolution of the idea of physical reality*", from the book "*James Clerk Maxwell: a commemoration volume*" (C.U.P., 1931).

And so at last we come to quantum mechanics, which was to remain a thorn in Einstein's life to the end of his days, despite the enormous role he had played in creating it, and in setting in motion the development of the revolutionary ideas it embodied.

2.3 (b) Quantum Mechanics: The great irony, of course, is that Einstein appreciated long before anyone else quite how revolutionary quantum mechanics had to be – even in 1905, he made this clear in his theory of light quanta – and the statistical nature of the theory was clear to him far in advance of the rest of the physics community at that time. And yet he could not accept its final form.

Why was this? From the discussions given above it is clear that quantum mechanics, as embodied in the form given by Heisenberg, Schrodinger, and Dirac, violated his ideas about what the 'ultimate theory' should look like, in a very fundamental way. The situation came to a head in his famous debates with Bohr, and it is useful to begin with a short summary of his viewpoint on his after some of the dust had settled:

" *Of the orthodox quantum theoreticians whose position I know, Niels Bohr's seems to me to come nearest to doing justice to the problem. Translated into my own way of putting it, he argues as follows:*

If the partial systems A and B form a total system which is described by its Ψ*-function* Ψ_{AB}*, there is no reason why any mutually independent existence (state of reality) should be ascribed to the partial systems A and B viewed separately,* not even if the partial systems are spatially separated from each other at the particular time under consideration. *The assertion that, in this latter case, the real situation of B could not be (directly) influenced by any measurement taken on A is, therefore, within the framework of quantum theory, unfounded and (as the paradox shows) unacceptable.*

By this way of looking at the matter it becomes evident that the paradox forces us to relinquish one of the following two assertions:

(1) the description by means of the Ψ*-function is* complete

(2) the real states of spatially separated objects are independent of each other.

On the other hand, it is possible to adhere to (2), if one regards the Ψ*-function as the description of a (statistical) ensemble of systems (and therefore relinquishes (1)) . However, this view demolishes the framework of the 'orthodox quantum theory.'....*"

Einstein, in Schilpp, LLP, "reply to criticisms", p. 681 (1949)

What Einstein has described here is of course the thought-experiment which was first discussed in the famous EPR (Einstein-Podolsky-Rosen) paper in 1935. The main point of this paper was precisely to show that there was what we now call an incompatibility between the idea of 'Einstein locality' (ie., that what is physically real be subject to the Principle of Relativity, so that reality be confined to local regions of spacetime) and quantum mechanics, which seemed to allow for physical states of systems which could not be so localized. That quantum mechanics does allow such states, and that this conflicts with what appears to be a very general notion of reality, is the EPR paradox.

The above description by Einstein of the EPR argument is succinct but perhaps too telegraphic. It is worthwhile giving a more complete description of it. This is done in the notes on Quantum Mechanics in much more detail, along with a discussion of more recent developments; and one can also look at the EPR paper itself (although this does involve arguments which require a training in physics to understand). However Einstein also felt that the arguments had not been given in their most transparent form in the EPR paper, so let's look at a more lengthy summary of the EPR argument given by Einstein himself:

"*Physics is an attempt conceptually to grasp reality as it is conceived independently of its being observed. In this sense one speaks of 'physical reality'. In pre-quantum physics there was no doubt as to how this was to be understood. In Newton's theory, reality was determined by a material point in space and time; in Maxwell's theory, by the field in space and time. Now if one asks - does a* ψ*-function of the quantum theory represent a real factual situation, in the same sense in which this is the case for a material system of points or an electromagnetic field, one hesitates to to reply with a simple yes or no. Why? What the* ψ*-function (at a definite time) answers, is this question: what is the probability of finding a definite physical magnitude q (or p) in a definitely given interval, if I measure it at time t? The probability is here to be viewed as an empirically determinable, and therefore certainly as a 'real' quantity,* *which which I may determine if I create the same ψ-function very often and perform a q-measurement each time. But what about the single measured value of q? Did the respective individual system have this q-value even before the measurement? To this question there is no definite answer within the framework of the existing theory, since the measurement is a process which implies a finite disturbance of the system from outside; it would therefore be thinkable that the system obtains a definite numerical value for q (or p), ie., the measured numerical value, only through the measurement itself. For the further discussion of this I will assume two physicists, A and B, who each represent a different conception of the real situation as embodied in the ψ-function.*

A*: The individual system, before the measurement, has a definite value of q (otherwise p) for all variables of the system, and more specifically*, that value *which is determined by a measurement of this variable. Proceeding from this conception, he will state: the ψ-function is no exhaustive description of the real situation of the system, but an incomplete description; it expresses only what we know on the basis of former measurements concerning the system.*

B*: The individual system (before the measurement) has no definite value of q (or else p). The value of the measurement only arises in cooperation with the unique probability which is assigned to it by the ψ-function, only through the act of measurement itself. Proceeding from this conception, he will (or, at least, he may) state: the ψ-function is an exhaustive description of the real state of the system.*

We now present to these two physicists the following situation. Suppose we have a system which at the time t of our observation consists of 2 partial systems S_1 and S_2, which at this time are spatially separated and (in the sense of classical physics) are without significant interaction. The total system is assumed to be completely described by a known quantum-mechanical ψ-function Ψ_{12}. All quantum theorists now agree that if I make a complete measurement of the state of S_2, I get from the results of the measurement, and from Ψ_{12}, an entirely definite ψ-function ψ_2 of the system S_2. The character of ψ_2 then depends on what kind *of measurement I undertake on S_1.*

Now it seems to me that one may speak of the real factual situation of the partial system S_2. Of this situation, we know to begin with, ie., before the measurement on S_1, even less information than we know of the total system described by Ψ_{12}. But on one supposition we should, in my opinion, hold fast: the real factual situation of the system S_2 is independent of what is done with the system S_1, which is spatially separated from the former. However, according to what kind of measurement I perform on S_1, I get a quite different state ψ_2 for the second partial system. However, the real situation for S_2 must be independent of what happens to S_1. Nevertheless, according to quantum mechanics, we see it is possible to get, according to one's choice of measurement on S_1, different states ψ_2 for S_2. One can escape this result only by either assuming that the measurement on S_1 telepathically changes the real situation of S_2, or by denying independently real situations to systems which are spatially separated from one another. Both alternatives appear to me to be completely unacceptable.

If now the physicists A and B accept these considerations as valid, then B will have to give up his position that the ψ-function gives a complete description of a real factual situation. For if this were the case, it would be impossible for two different ψ-functions to describe the same state, or factual situation, of S_2. "

A Einstein, in Schilpp, LLP, "Autobiographical Notes", pp 82-87.

Now it is clear from these passages that it was not only the mathematical structure and the physical framework of the theory that bothered Einstein. After all, he had such problems with his own theory of general relativity; and moreover, he had continued to make revolutionary advances in quantum theory itself, while all the while aware of the peculiar features that were being revealed. So Einstein was no stranger to the philosophical manouevre of 'suspension of disbelief', ie., the adoption of a view which one provisionally accepts in order to make headway through the unknown, while all the while reserving one's final judgement in the full knowledge that something better has to come along once things have become more clear. But the theory of quantum mechanics as it fianly settled down violated, for him, a much more fundamental set of beliefs in what constituted 'physical reality', and the *objects* of physical reality.

So we are finally forced to ask: what exactly did he mean by this? Perhaps the most explicit discussion was in a letter to Born:

"*I just want to explain what I mean when I say that we should try to hold on to physical reality. We are ... all aware of the situation regarding what will turn out to be the basic foundational concepts in physics: the point-mass or the particle is surely not among them; the field, in the Faraday-Maxwell sense, might be, but not with certainty. But that which we conceive as existing ("real") should somehow be localized in time and space. That is, the real in one part of space, A, should (in theory) somehow "exist" independently of that which is thought of as real in another part of space, B. If a physical system stretches over A and B, then what is present in B should somehow have an existence independent of what is present in A. What is actually present in B should thus not depend on the type of measurement carried out in the part of space A; it should also be independent of whether or not a measurement is made in A. If one adheres to this program, then one can hardly view the quantum-theoretical description as a complete representation* *of the physically real. If one attempts, nevertheless, so to view it, then one must assume that the physically real in B undergoes a sudden change because of a measurement in A. My physical instincts bristle at that suggestion. However, if one renounces the assumption that what is present in different parts of space has an independent, real existence, then I don't see at all what physics is supposed to be describing. For what is thought to be a "system" is after all, just conventional, and I do not see how else one is supposed to divide up the world objectively so that one can make statements about parts.*"

"What must be an essential feature of any future fundamental physics?"

Letter to Max Born; from "The Born-Einstein letters, 1916-55" (Macmillan, 1971)

And thus we are brought back to consider the notion of 'objects' as fundamental both to human thought, and to the idea of 'physical reality'. We see how closely connected these two ideas became, at least in Einstein's later formulation of his philosophical point of view.

As is well known, Einstein never yielded in his position on this point. To the end of his life he maintained his belief that quantum mechanics was incomplete, and that his notion of physical reality must be correct. The two most important developments that have taken place since then, which cast this famous debate in a new light, are (i) the experimental verification that the non-local features of quantum mechanics really do exist, in phenomena ranging from quantum teleportation to quantum computation; and (ii) the extraordinary rise of General Relativity from a curiosity in the 1930's and 1940's, to an enormously powerful tool in modern astrophysics and cosmology, with stunning successes in regimes far beyond those envisaged by Einstein. This has created something of a crisis in modern physics, for we now have 2 theories (General Relativity and quantum mechanics) which are apparently incompatible on a very basic level, and yet which both work with a success beyond what anyone could have imagined. To try and confront the two theories is perhaps the single most important challenge facing modern physics. In this context an article by Einstein in 1950, which is apparently not widely known, seems almost extraordinary. In it he says:

This is the reason why all attempts to obtain a deeper knowledge of the foundations of physics seem doomed to me unless the basic concepts are in accordance with general relativity from the beginning. This situation makes it difficult to use our empirical knowledge, however comprehensive, in looking for the fundamental concepts and relations of physics, and it forces us to apply free speculation to a much greater extent than is presently assumed by most physicists.

I do not see any reason to assume that the heuristic significance of the principle of general relativity is restricted to gravitation and that the rest of physics can be dealt with separately on the basis of special relativity, with the hope that later on the whole may be fitted consistently into a general relativistic scheme. I do not think that such an attitude, although historically understandable, can be objectively justified. The comparative smallness of what we know today as gravitational effects is not a conclusive reason for ignoring the principle of general relativity in theoretical investigations of a fundamental character. In other words, I do not believe that it is justifiable to ask: What would physics look like without gravitation?

A Einstein, "On the Generalized Theory of Gravitation", Scientific American (April 1950)

In the year 2010 this passage looks almost prophetic - modern astrophysics sees evidence of strong-field phenomena everywhere from supernovae and neutron stars to supermassive black holes at galactic cores, and our understanding of cosmology would be quite primitive without the essential tool of General Relativity in strong gravitational fields. And so the problems raised by Einstein, including the EPR paradox, have become far more acute. Thus, it is seems impossible to see how one may reconcile General Relativity with quantum mechanics, in view of the fact that spacetime itself has to be seen as a physical object, and yet spacetime in General Relativity is still subject to requirements of locality.

Further discussion of these topics takes us into quantum mechanics itself. This is dealt with at more length elsewhere in the notes (see notes on Quantum Mechanics).

3. SUMMARY

Let us now summarize the epistemological credo of Einstein, and the crucial metaphysical factors which it incorporated. One can distinguish a number of key elements in this, all of which have been discussed in the foregoing:

(a) A view of the nature of thought and human thinking which is very much at variance with the typical Anglo-Saxon view - he laid great stress on unconscious and intuitive elements, and felt that much of human thinking was conducted on a very primitive and to some extent instinctive level. The importance of language and symbolic thought was of course well understood by him - ordinary language and also the language of mathematics allow to go far beyond what one might do with only the crutch of intuitive thinking. But this formal thinking rides on the surface of a deep ocean of more primitive mental processes. In this sense Einstein was very far, philosophically, from the more bloodless ideas of most of his contemporaries - a crude philosophical Neanderthal, as it were, amongst his aristocratic superiors.

(b) A clear influence on his ideas of the epistemology of Kant and of the British empiricists (and, in his early development, a more limited influence coming from Mach). The clash between Kant and Hume was important for Einstein. On the one hand he approved of the important role Kant allotted to metaphysics, and was clearly strongly influenced by Kant's attempt to resolve the paradoxes inherent in a purely empiricist view. On the other hand he was, at least most of the time, resolved to have his ideas constrained by experiment and observation - even though he quite rightly rejected the idea, still championed by many scientists even today, that science advances inductively. In many of his important writings, Einstein agreed tacitly or explicitly with Kant's idea of 'categories of understanding', even though he completely rejected Kant's idea that one could deduce what these categories might be. Instead, Einstein argued that we are free to choose our categories - that we indeed invent them, in a free play of the mind, and that this process of creative invention is fundamental to science - an idea diametrically opposed to the inductive method, and which inevitably makes science in part a metaphysical exercise. And yet, this creative play of the mind had to be constrained, quite ruthlessly, by what we observe around us for the categories concern not just our own mental creations, but the world as well - this is essential in Kant's view of the categories.

(c) This free play of the mind - a kind of mental dance between the world of thought and the physical world - was of enormous influence in the way science came to be conducted throughout the 20th century (and indeed, its influence was felt indirectly in many fields far from science). It is hard to imagine that theoretical physics would have developed in the same way without this style of thinking, and the modern style of doing theory relies essentially on it. And yet almost all theoretical physicists reject the philosophical side to it, preferring to allow their creativity to stay confined to the purely mathematical world of formal theory. From Einstein's point of view, this was a victory of style over substance - but physicists have largely rejected this criticism, largely because of the success of the theoretical framework of quantum field theory, and because of the failure of Einstein's criticisms of quantum mechanics. It seems very clear, however, that this battle is not over. Einstein's final views on the nature of Physical Reality have clearly not been vindicated in detail - indeed they have been found to be incorrect. But nobody has found a better way of understanding how we are to understand reality, and many physicists, honestly admitting that there is something 'real' about the world around us (and of which we are but a part), would agree with Einstein that the standard view of quantum mechanics is simply inadequate, and that there must be something beyond quantum mechanics. The continuing inability of physics to resolve the contradictions between quantum theory and General Relativity, and the overwhelming empirical and predictive success of both theories, indicates to many physicists that the next theory must go beyond both of these.

(d) The absolutely crucial role of a kind of 'cosmic faith' in Einstein's philosophical make-up. This involved a humility before the universe, a refusal to imagine that humans played any important role in it whatsoever, or that 'God' was there to guide humans in any way; and an astonishment that we were capable of understanding anything significant at all, about either ourselves or the larger world that we can observe. His recognition that, *a priori*, there is no real justification for our capacity for understanding anything in the universe, or for its apparent rationality and its structure, and the inevitable conclusion that this was essentially a miracle, beyond out understanding, was something he returned to again and again - it was integral to his beliefs, and gave him an impressive caution and lack of dogmatism in most of his opinions. Such a humility and flexibility in his approach was, as he recognized, a characteristic of many philosophers and some men of faith before him - but also he made it a part of his scientific approach, and in doing this, he utterly transformed our picture of the universe (indeed, before Einstein, the idea that science could even talk about the universe as a whole was hardly imagined). Thus one sees an almost seamless connection between Einstein's cosmic faith and his scientific methodology, as well as his basic moral attitude, at least in later years. It is given to few people to achieve such a harmony between thought, belief, and action.

Of course, the fly in the ointment here was his failure to deal with quantum mechanics. We have seen that at the very core of his philosophy was the notion of a physical object, which was very much imported from Kant, with the proviso that one be flexible about the categories. This inevitably committed him to the belief that Nature was in its essence unknowable to us; but nevertheless he felt we could glimpse some of the ultimate reality, however imperfectly, and that the categories of our understanding, the 'free creations of the mind', had some relationship to this - indeed, they were constrained to be in correspondence with what appeared, at least in part, to be a rational universe, by experiments. Fundamental to the notion of a physical object, for Einstein, was something that he himself had discovered, viz., that it had to be localized in spacetime.

That this apparently led to a fundamental conflict with quantum mechanics was the problem that bothered Einstein to the end of his life. However he was occasionally able to laugh at the situation, both at quantum mechanics as a theory:

"*I close these expositions, which have grown rather lengthy, concerning the interpretation of quantum theory, with the reproduction of a brief conversation which I had with an important theoretical physicist. He: I am inclined to believe in telepathy. I: This has probably more to do with physics than with psychology. He: Yes.....*"

Einstein, in Schilpp, LLP, "reply to criticisms", p. 683 (1949)

and at his own hubris in setting himself up against the massive evidence in support of the theory:

"*Whoever undertakes to set himself up as a judge of Truth and Knowledge is shipwrecked by the laughter of the gods*"

from A Einstein, "*Mein Weltbild*", 1931

Notice that these remarks were made shortly after the first set of debates that he had with Bohr, at the Solvay meetings - the EPR paper, and the long search for a unified field theory, were still to come. By this time Einstein was already famous world-wide, and having to deal with the consequences of this fame; and his General Theory was largely established, although few physicists understood or cared much about it. The situation in these respects was not to change in his lifetime - he was as isolated in his beliefs at his death, at least amongst scientists, as he was at the time he made these remarks.

What legacy has been left in the world by Einstein's philosophical ideas? This is a hard question to answer, and it may well be too early to try. He himself pursued the idea of a unified field theory – but not a quantum mechanical one – until the end of his life. The dream of such a theory, after practically disappearing at the end of the 1950's, received a huge stimulus from the success of the electroweak unification and the subsequent standard model – it is currently being pursued in the field of string theory, in a form which has very little in common with Einstein's ideas. After a long period during which the Copenhagen interpretation of quantum theory reigned almost unquestioned, work in various fields, as well as the unresolved nature of the paradoxes raised by quantum mechanics, has led many to question the standard interpretation of quantum mechanics, and even to propose alternative theories. Yet in its application to every area of physics, including astrophysics, cosmology, statistical and condensed matter physics, chemistry, and biology, the success of quantum mechanics has been overwhelming. Even more strikingly, the EPR paradox has been realized in the lab, with a complete verification of the results predicted by quantum mechanics, in apparent defiance of Einstein's philosophical credo.

And yet, as noted above – there is still no sign of a quantum theory of gravity, or of a theory which goes beyond both quantum mechanics and General Relativity to give a unified treatment of all physical phenomena currently under study. And the successes of Einstein's General Relativistic ideas multiply every year - the huge subject of relativistic astrophysics, not to mention cosmology, would hardly exist without it. And so on the scientific side, the jury is still out.

On the more philosophical side, the immediate impact of Einstein's epistemological ideas was huge - they played a decisive role in the formulation of Popper's theory of falsification, which has been adopted by most working scientists in the world (not just physics). Yet in many ways his unique amalgam of the rational and intuitive, and of the formal and primitive, in his credo, has yet to be realized in any more systematic subsequent philosophy. Most philosophy having any real impact in the last 70 years has focussed on moral and political themes. The world is still waiting for a philosopher or a philosophical movement which is capable of taking on the revolutionary discoveries in physics and biology of the last 100 years, and absorbing them into a new metaphysical and epistemological framework.

Never before in history has a scientist or thinker of such distinction as Einstein been subject to such a close examination of his life and work. It would have been nice to know more about the lives and personalities of Newton, or Shakespeare, or da Vinci, or, reaching further back, to Plato, Aristotle, and Archimedes (not to mention figures such as Confucius, Christ, and Mohammad). The further back we go, the more the lives of these people is wrapped in mystery and myth, and the less of what we read is reliable. With Einstein this is not the case – the first-hand documentary information on him is huge, and there are still people alive who knew him. And yet, as mentioned near the beginning of these notes, one has to sort through an enormous quantity of false information about him, even now, to find what is true. Such is the prestige now attached to Einstein's name, both in science and elsewhere, that we find him attached to ideas which he would hardly have countenanced, in areas ranging from politics and religion to the most outlandish speculations about the universe. All of this should serve as a strong caution when reading anything about the lives of important figures of the past.

Nevertheless, quite remarkably, his work continues to serve as an inspiration to all working scientists, and it continues to exercise a fundamental influence on research directions in physics to this day. We have already seen this in the discussion of the contradictions between quantum theory and General Relativity, in the abiding fascination physicists have with the idea of a 'unified field theory', and in the endless fascination with the paradoxical features of quantum theory which was launched by the EPR paper. These are relics of Einstein's later years; but of course his work in

FIG. 5: A railway carriage in an abandoned railway yard, 2 km outside the town of Uyuni, in the mountains of Bolivia. Painted on the train engine are the field equations of General Relativity (written in c.g.s. units!) It is apparently not known who painted these, nor whether they understood what they were writing.

Relativity, and his early work on quantum mechanics and statistical mechanics, are now pillars holding up much of contemporary physics, as important, if not more important, then those erected by Newton. More generally one sees Einstein's influence in the fundamental change that has taken place, in the way in which theoretical physics is done, since he burst upon the scene at the beginning of the 20th century. Regarded by most physicists as not much more than the handmaiden of experimental physics since the time of Newton, theoretical physics acquired a life and style of its own after Einstein, unconstrained by the burden of induction, or by the need to only address *observed* facts. In a return to ideas first clearly expressed by Huyghens, Einstein made the idea of speculative theory, with its emphasis on prediction, an accepted part of physics - and the justification for this was to be found in the spectacular success of his ideas in the realm of empirical prediction. The idea that one of the essential tasks of theory is to extend the boundaries of our understanding by doing this kind of daring predictive work, following the dictates of theoretical principle rather than existing empirical facts, hardly existed before Einstein. It is still not popular in many quarters (not least in the editorial offices of some journals, and in the attitudes of some experimental physicists); but it is here to stay.

In the wider world, his reputation has only grown with the passing years. His life has about it a combination of wisdom and simplicity, and of a seeker whose work was very much integrated with his philosophical and moral beliefs. His unprecedented success in his endeavours not only made him an enduring compass for the whole scientific world, but has also continued to endear him to the wider public, which has accorded to him a trust and respect given to no other scientist in history. When Einstein died in 1955 he was one of the most famous people in the world, and the object of almost universal veneration. By the end of the 20th century his reputation had only increased: he was not only voted by physicists to be the greatest physicist of all time, and by Time magazine to be the "Person of the Century" (ahead of Churchill, Gandhi, Mandela, and Franklin D Roosevelt); but the readers of 3 newspapers (the Toronto 'Globe and Mail', the 'Times' of London, and 'Le Monde' of Paris) also voted him to be the most important person in history over the last 1000 years. Curiously, the editors of both the Globe and Mail and the Times were somewhat mystified by this result – which illustrates how easily the self-absorbed and often rather ignorant intelligentsia of a nation may be left behind by the general public. The public attitude was better summed up by the well-known cartoonist Herbert Block, on the occasion of his death (see Figure 6 below):

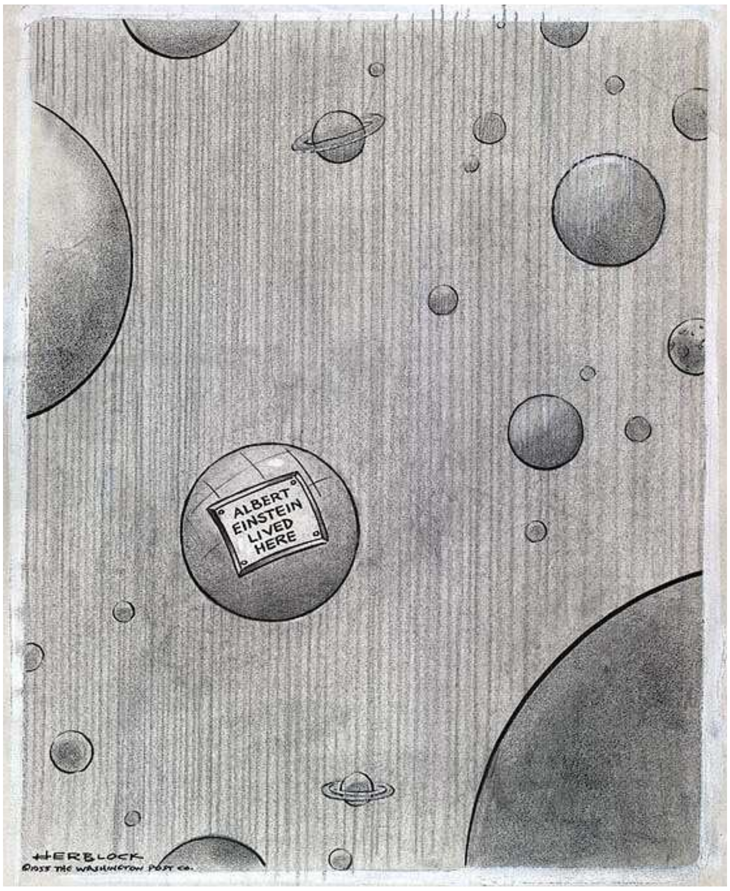

FIG. 6: The cartoon which appeared in the Washington Post the day after Einstein died, by the celebrated cartoonist Herbert Block - it summed up the attitude of the American public in 1955 towards Einstein, his scientific achievements, and his political and moral ideals.