International Journal of Modern Physics A
Vol. 21, No. 15 (2006) 3031–3038

World Scientific
www.worldscientific.com

ALBERT EINSTEIN: OPPORTUNITY AND PERCEPTION*

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I

The year 1905 has been called Albert Einstein's "Annus Mirabilis." It was during that year that he caused revolutionary changes in man's primordial concepts about the physical world: space, time, energy, light and matter. How could a 26-year-old clerk, previously unknown, cause such profound conceptual changes, and thereby open the door to the era of modern scientific technological world? No one, of course, can answer that question. But one can, perhaps, analyze some factors that were essential to his stepping into such a historic role.

First of all, Einstein was extraordinary lucky: he was born at the right time, and was at the peak of his creative powers when the world of physics was shuddering from multiple crises. In other words, there was the lucky opportunity for him to change the course of physics, an opportunity unmatched, perhaps, since the time of Newton. Such lucky opportunities occur very very infrequently. In E. T. Bell's *Man of Mathematics*, Lagrange (1736–1813) was quoted as having said:

> *Newton was assuredly the man of genius par excellence, but we must agree that he was also the luckiest: one finds only once the system of the world to be established.*

Here Lagrange was referring to the words in Newton's introduction to the third and final volumes of his great *Principia Mathematica*.

> *I now demonstrate the frame of the system of the world.*

*Talk given at The 8th International Symposium on Foundations of Quantum Mechanics in the Light of New Technology (ISQM-Tokyo '05), 22–25 August 2005, Japan.

Fig. 1. Einstein as a Swiss patent clerk in 1905 when he revolutionized fundamental physics through the creation of the special theory of relativity.

While Lagrange was obviously envious of Newton's lucky opportunity, we detect little sentiment of a similar nature in what Einstein had publicly said of Newton:

> *Fortunate Newton, happy childhood of science ... In one person he combined the experimenter, the theorist, the mechanic and, not least, the artist in exposition. He stands before us strong, certain, and alone ...*

Turning to Einstein's own times, he had the opportunity to amend the system created by Newton more than 200 years ago. This lucky opportunity was of course open also to all scientists of his time. Indeed electrodynamics in a moving system had been a subject of intense discussions since the Michaelson–Morley experiment, first performed in 1881, repeated with greater precision in 1887. Amazingly Einstein was already intensely interested in this topic while still a student in Zurich. He had written to his future wife Mileva in 1899:

> *I returned the Helmholtz's volume and am now rereading Hertz's propagation of electric force with great care because I didn't understand Helmholtz's treatise on the principle of least action in electrodynamics. I'm convinced more and more that the electrodynamics of moving bodies as it is presented today doesn't correspond to reality, and that it will be possible to present it in a simpler way.*
>
> [From Albert Einstein/Mileva Marić, *The love letters*, Edited by Renn & Schulmann, Translated by Smith.]

The search for this simpler way led, six years later, to special relativity.

Many other scientists were also deeply interested in the subject. Poincaré (1854–1912), one of the two towering mathematicians at the time, was actively working on the same problem. Indeed the name *relativity* was not invented by Einstein. It was invented by Poincaré. One reads in his speech delivered one year before 1905 (in *Physics for a New Century*, AIP publication on History, Vol. 5, 1986):

> *The principle of relativity, according to which the laws of physical phenomena should be the same, whether for an observer fixed, or for an observer carried along in a uniform movement of translation; so that we have not and could not have any means of discerning whether or not we are carried along in such a motion.*

This paragraph not only introduced the term "relativity," but showed amazing insight which is absolutely correct *philosophically*. However, Poincaré did not understand the full implication in *physics* of this paragraph: later paragraphs in the same speech showed that he failed to grasp the crucial and revolutionary idea of the *relativity of simultaneity*.

Einstein was also not the first to write down the great transformation formula:

$$x' = \gamma(x - vt)\,, \quad y' = y\,, \quad z' = z\,,$$

$$t' = \gamma\left(t - \frac{vx}{c^2}\right), \quad \gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

which had already been given by Lorentz (1853–1928), after whom it was, and still is, named. But Lorentz also failed to grasp the revolutionary idea of the relativity of simultaneity. He wrote later in 1915:

> *The chief cause of my failure was my clinging to the idea that only the variable t can be considered as the true time and that my local time t' must be regarded as no more than an auxiliary mathematical quantity.*
>
> [cf. Pais' biography of Einstein, p. 167]

That is, Lorentz had the *mathematics*, but not the *physics*, and Poincaré had the *philosophy*, but also not the *physics*. It was the 26-year-old Einstein who dared to question mankind's primordial concept about time, and insisted that *simultaneity is relative*, thereby opening the door to the new physics of the microscopic world.

Almost all physicists today agree that it was Einstein who had created special relativity. Is that fair to Poincaré and Lorentz? To discuss this question let us quote from A. N. Whitehead [in *The Organization of Thought*, (Greenwood Press, 1974), p. 127]:

> *To come very near to a true theory and to grasp its precise application, are two very different things, as the history of science teaches us. Everything of importance has been said before by somebody who did not discover it.*

Lorentz and Poincaré indeed did seize the lucky opportunity of the time, and had worked very hard on one of the main problems, the electrodynamics in a moving system. But they both missed the crucial key point. They missed because they had "clung" to old concepts, as Lorentz himself later had said. Einstein did not miss because he had a **freer perception** of the meaning of space–time.

To have a **free perception**, one must simultaneously be close to the subject under investigation, and yet be able to examine it at a **distance**. Indeed the often used term **distant perception** shows the necessity of maintaining a certain distance in any penetrating discernment. But distant perception alone is not enough. It must be matched by a detailed close-up understanding of the problem at hand. It is the ability to freely adjust, assess and compare the close-up and distant views that constitutes **free perception**. Pursuing this metaphor, we might say that Lorentz had failed because he had *only* a close-up view, while Poincaré had failed because he had *only* a distant perception.

The great Chinese esthetician 朱光潜 (1897–1986) had emphasized the importance of "psychical distance" in artistic and literary creativity. I think that idea is very much the same as the distant perception discussed above, but in another area of intellectual activity. In the brilliant definitive scientific biography of Einstein, *Subtle is the Lord*, by Pais, the author chose one word to describe Einstein's character: **apartness**, and quoted at the beginning of Chapter 3:

> **Apart** ... *4. Away from others in action or function; separately, independently, individually.*
>
> [Oxford English Dictionary]

Indeed, **apartness, distance**, and **free perception** are related concepts, referring to an essential element in all human creativity, in science, in art, and in literature.

Another historic achievement of Einstein's in 1905 was his paper "*On a heuristic point of view concerning the generation and conversion of light*" written in March of that year. Historically this paper launched the revolutionary idea of light as quanta with discrete energy $h\nu$. The constant h had already been introduced by Planck in 1900 in his bold theoretical study of black body radiation. In subsequent years, however, Planck got cold feet, and began to hedge. In stepped Einstein in 1905, who not only did not hedge, but pushed forward courageously with his "heuristic point of view" of light quanta. That this courageous push was not generally appreciated can be gathered from the following sentences in a document written by Planck, Nernst, Rubens and Warburg, eight years later in 1913, when they proposed Einstein for membership in the prestigious Prussian Academy:

> *In sum, one can say that there is hardly one among the great problems in which modern physics is so rich to which Einstein has not made a remarkable contribution. That he may sometimes have missed the target in his speculations, as, for example, in his hypothesis of light-quanta, cannot really*

be held too much against him, for it is not possible to introduce really new ideas even in the most exact science without sometimes taking a risk.

[From Pais, *Subtle is the Lord*, 1982, p. 382]

Here the ridiculed "*hypothesis of light-quanta*" referred to Einstein's bold proposal of 1905 mentioned above. Despite such general derision, Einstein pushed *further ahead*, and in papers of 1916–1917 established the value of the momentum of the light quantum, leading later to the epoch-making understanding of the Compton effect in 1924.

The history of the birth of the revolutionary idea of the light quanta can be summarized as follows:

$$\begin{aligned} &1905 : \text{Einstein's paper on } E = hv \\ &1916 : \text{Einstein's paper on } P = E/c \\ &1924 : \text{Compton effect} \end{aligned}$$

Throughout these years, before the Compton effect was established in 1924, Einstein was **alone** in his insightful perception, at a time when entrenched conviction about waves was sacred to the whole physics community.

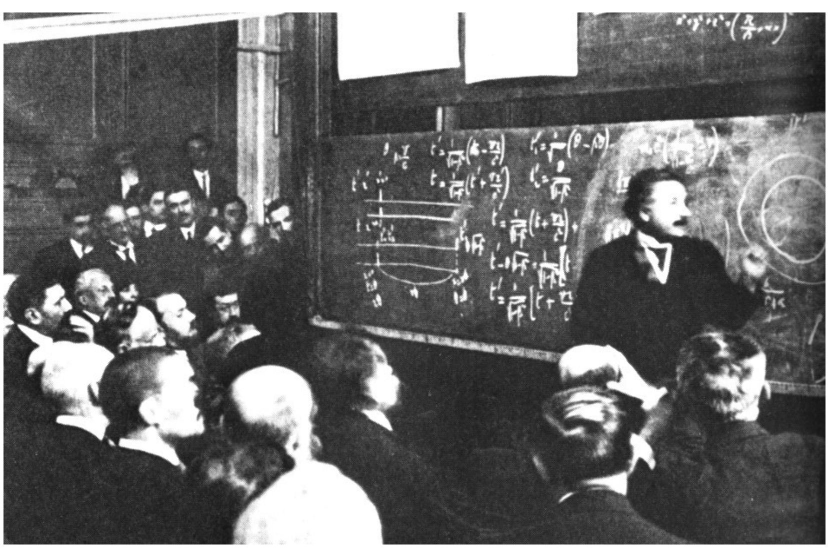

Fig. 2. Einstein giving a lecture in 1922 at the College de France in Paris.

II

Between 1905 and 1924 Einstein's main research interests were focused on the general theory of relativity. As a scientific revolution general relativity is unique in the history of mankind. The grandeur of its conception, its beauty, its sweeping scope, its spawning the awesome science of cosmology, and the fact that it was conceived and executed by one single person, reminds me of the act of *creation* in the old testament. (And I wonder whether Einstein himself had thought of this comparison.)

Fig. 3. Einstein in his study in his home on Haberlandstraße in Berlin.

Of course, one would also naturally think of other scientific revolutions, such as Newton's *Principia*, special relativity, and quantum mechanics. Some differences: Newton's work had grandeur, had beauty, had sweeping scope. Yes. But he had before him the works of Galileo, of Kepler and of earlier mathematicians and philosophers. He was not alone at the time in searching for the law of gravity. Special relativity and quantum mechanics were both profound revolutions. But they were hot topics worked on by many people at the time. Neither was the creation of a single person. For general relativity, Einstein did not seize any opportunity. He created the opportunity. Alone, through deep perception, he conceived the problem and after seven or eight years of lonely struggle produced a new *system of the world* of unimaginable beauty. It was an act of pure *creation*.

III

General relativity represented the geometrization of the gravitational field. It quite naturally led to Einstein's push for the geometrization of the electromagnetic field. Thus was born his idea to formulate an overall geometrization of all forces of nature, a *unified field theory*, which gradually evolved into his main research effort during the latter part of his life. The last seminars that he gave, for example, were in 1949–1950 at the Institute for Advanced Study in Princeton, and the subject was his latest attempt to incorporate the field strengths $F_{\mu\nu}$ of the electromagnetic field into an unsymmetrical metric $g_{\mu\nu}$. This attempt, as well as his earlier attempts in the same direction, was also unsuccessful.

As a consequence of this lack of success, and also because of the fact that, starting in the late 1920's, he directed his attention almost exclusively to this search, neglecting such newly developing fields as solid state physics and nuclear physics, he was often criticized, even ridiculed. His devotion to the unified field theory was called an *obsession.* An example of this criticism is what I. I. Rabi (1898–1988) had said in 1979 at the Einstein centennial in Princeton:

> *When you think of Einstein's career from 1903 or 1902 on to 1917, it was an extraordinarily rich career, very inventive, very close to physics, very tremendous insights; and then, during the period on which he had to learn mathematics, particularly differential geometry in various forms, he changed. He changed his mind. That great originality for physics was altered . . .*

Was Rabi right? Did Einstein change? The answer is, *Einstein did change.* Evidence for this change can be found in his Herbert Spencer lecture of 1933 bearing the title *On the Method of Theoretical Physics*:

> *. . . the axiomatic basis of theoretical physics cannot be extracted from experience but must be freely created . . .*
>
> *Experience may suggest the appropriate mathematical concepts, but they most certainly cannot be deduced from it . . .*
>
> *But the creative principle resides in mathematics. In a certain sense, therefore, I hold it true that pure thought can grasp reality, as the ancients dreamed.*

One may or may not agree with these very concise statements, but one has to agree that they powerfully and emphatically describe Einstein's perception in 1933 about how to do fundamental theoretical physics, a perception that represents a profound change from his earlier days.

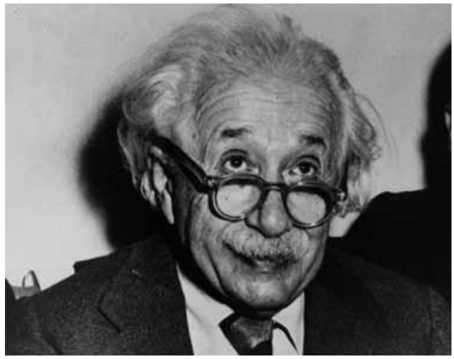

Fig. 4. Einstein in Princeton.

So, Einstein did change. He himself was keenly aware of this change. In the *Autobiographical Notes*, published when he was 70 years old, we read:

> ... *and it was not clear to me as a student that the approach to a more profound knowledge of the basic principles of physics is tied up with the most intricate mathematical methods. This dawned upon me only gradually after years of independent scientific work.*

It is evident that in this passage the *independent* scientific work was his long struggle to formulate general relativity during the period 1908–1915. That long struggle had changed him. Did he change for the better? Rabi would say: no, his changed perception had become a futile obsession. We would say: yes, his changed perception has altered the future course of development of fundamental physics.

Einstein's perception had permeated the very soul of the research in fundamental theoretical physics in the 50 years since Einstein's death, serving as a lasting testimonial to his courageous, independent, obstinate and perceptive greatness.