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100 Years ago: Nobelprize in Physics awarded to Albert Einstein

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It is not easy to fix the correct date for remembering this anniversary. In November 1922 the Nobel Commitee decided that Einstein should receive the Physics prize for the year 1921 and invited him to take part in the usual festivities at Stockholm in December of 1922. For reasons described below, Einstein was unable to follow this invitation but later agreed to acknowledge the receipt of the Prize by delivering a special lecture of his choice in July 1923, not in Stockholm but in Gothanburg instead.

The story around the Nobel Prize of Albert Einstein began in the first half of 1905. Although working full time, i.e., 48 hours a week, as a technical expert 3rd class at the Federal Patent Office in Bern, he submitted, within a little more than 3 months, four manuscripts for publication in the prestigious journal *Annalen der Physik*. In retrospect, the content of three of them was of exceptional scientific quality such as to qualify him for a Nobel Prize nomination. The fourth paper was actually his doctoral dissertation which he submitted to the University of Zurich at the end of April but appeared, a year later, also as a regular paper in the *Annalen*. His alma mater, the Federal Polytechnic in Zurich was, at the time, not yet allowed to grant doctoral degrees. A fifth manuscript, submitted somewhat later in that year, contains the equation $E = mc^2$, no doubt the most widely known relation in physics, even among the general public. Considering the circumstances, this scientific performance is absolutely amazing and in this connection the term *annus mirabilis* 1905 is well justified.

The titles of the three prizeworthy articles mentioned above are somewhat obscure for non-specialists. The first, submitted on 17 March, is entitled "*Ueber einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt*". In this work, Einstein got convinced that observations of the interaction of light with matter imply the existence of lightquanta, known today as photons. He deduced that the energy of individual photons only depends on the frequency ν of the radiation, i.e., $\varepsilon_{ph} = h\nu$, whereby h is the constant introduced by Planck in his pioneering work on the black-body radiation spectrum in late 1900.

With this hypothesis Einstein succeeded in explaining available experimental results concerning electrons emitted from metal plates by light absorption, also known as photoelectrons, as well as the well known Stokes' rule related to the photoluminescence of certain substances. The existing results of observations of both phenomena were, at the time, not understood on classical grounds, assuming that radiation is carried by Maxwell-type electromagnetic waves. In particular, Einstein concluded that the maximum energy of an individually emitted photoelectron was given by $\varepsilon_{el}^{max} = h\nu - P$, where P is the energy needed for the electron to leave the surface of the metal plate. The latter equation was later termed „the law of the photoelectric effect“. On classical grounds it was expected that this maximum energy would correlate with the intensity of the impinging radiation which, however, was not observed experimentally. Of course, Einstein realized the basic difference between the concepts of individual light particles and the very successful description of light propagation on the basis of Maxwell's electromagnetic waves. However, at that time he saw no way out of this dilemma, a fact that bothered him for years to come. In his own words, in a letter to a colleague, he judged his work as very revolutionary. As we shall see below, this view was well justified.

The second manuscript, entitled "*Ueber die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen*" was submitted on 11 May. In a theoretical study, Einstein investigated the motion of small particles suspended in liquids at rest on the basis of the molecular-kinetic theory of heat. He compared the results of his reflections and conclusions with the results of experimental observations and, in this way, achieved an indirect proof for the existence of smallest units of matter in the form of atoms and molecules, at the time still a disputed issue. Quite unexpected is Einstein's conclusion that an experimental determination of Avogadro's number is possible with a light microsope, still a truly amazing fact.

A masterpiece with respect to both new thinking and its presentation was the third article, submitted at the end of June and entitled "*Elektrodynamik bewegter Körper*". In it, Einstein formulated what he termed the principle of relativity which, among other things, requests that no physical experiment can verify the state of a body at absolute rest. For mechanical experiments this fact was known for a very long time. Einstein now postulated that, as a matter of principle, this also had to be true with respect to optical and other electromagnetic phenomena. In particular this implies that, in empty space, the speed of light cannot be varied by varying the motion of the light source, a conclusion that is only hard to grasp intuitively. It also follows that the simultaneity of events occurring at different sites in space is a relative concept and that time and space can no longer be regarded as independent of each other. This new point of view, summarized in the theory of relativity (later, after his creation of the *generalized theory* of relativity, Einstein termed his earlier theory of 1905 as the *special theory of relativity*), stirred the interest of highly regarded and competent colleagues and promoted Einstein's prestige rather quickly. The conclusion which Einstein regarded as the most important of this new theory, the equivalence of energy and mass in the form of the above mentioned equation, whereby E is to be understood as the rest energy of the mass m, was submitted for publication at the end of September 1905.

During the following year, in 1906, Einstein applied a generalized interpretation of the lightquantum hypothesis to explain a phenomenon related to thermodynamic properties of condensed matter. Following the findings of the previous year he saw the need to modify the classical perception of the molecularkinetic theory of heat in the sense that energy transfer can only happen via individual energy quanta. In this way he succeeded in finding an explanation for the up till then puzzling temperature dependence of the specific heat of solids well below room temperature. It is fair to state that in this way he also initiated the modern theory of condensed-matter physics.

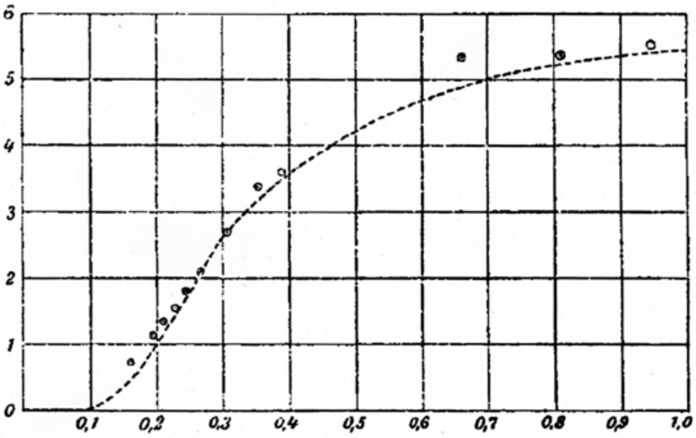

Fig. 1: Fit of Einsteins calculation of the temperature dependence of the specific heat C(T) of diamond. The experimental data (circles) are reported in H. F. Weber, Ann. Phys. ***154****, 367 & 533 (1875). Horizontal axis: x = T(k/hν); vertical axis y = C(T) in gramcalories. The best fit (broken line) is obtained with hν/k = 1300 K, with k denoting Boltzmann's constant.*

Because of all these pioneering contributions, Einstein, who had not yet reached the age of 30, was soon regarded by some, as one of the leading theoretical physicists, at least in Europe. It was therefore not surprising that, in 1909, he was invited to the annual *Versammlung Deutscher Naturforscher und Aerzte*, gathering in Salzburg in that year. It was expected that he would present his work related to the theory of relativity. Instead he chose to speak about the problem that really bothered him constantly and therefore his lecture, based on his earlier work in 1905 mentioned above, was entitled "*Zur Entwickelung unserer Ansichten über das Wesen und die Konstitution der Strahlung*". His presentation was met with severe skepticism or even rejection, however. The reason for this was mainly the obvious difference between the view of radiation as consisting of individual lightquanta or -particles and the very successful interpretation of light as Maxwell's propagating electromagnetic waves.

Another invitation, soon to follow in 1911, was to participate at the first Solvay Conference to be held in Brussels, sponsored by the Belgian industrialist Ernest Solvay. The meeting was intended to bring together a few but then leading scientists – Marie Curie was the only female person present – in order to discuss the most recent developments of the theories of heat and aspects of the then still new and much debated quantum physics. The participation of Einstein, only 32 years old, reflected his acknowledged competence in these fields and, indeed, he played a major role in the discussion sessions. Personally he judged the scientific content of the debates as not very enlightening because for him, nothing new emerged.

In retrospect the most important recognition of his contributions was the first nomination for the Nobel prize in Physics in 1910, submitted by the well known German physicochemist Wihelm Ostwald. Ten years earlier, Einstein had applied for an assistantship with Ostwald without success. Ostwald argued that the significance of the theory of relativity ought to be regarded as high as the discovery of the principle of energy conservation more the 50 years ago. During the following years up to 1920, with the exception of 1911 and 1915, Einstein was nominated for the Prize by different persons and with various justifications; none of them was successful, however.

Einstein's performance was also acknowledged in the academic sector with offers for professorships. He joined the University of Zurich (1909- 1910), the German University in Prague (1910-1912) and the Federal Institute of Technology (ETH) in Zurich (1912-1914). While at ETH, Einstein mainly collaborated with his former study colleague and now professor of mathematics Marcel Grossmann towards a General Theory of Relativity and Gravitation. A first draft (Entwurf) of the theory separated in two parts was ready in September 1913. Einstein was responsible for the physical part and Grossmann wrote the mathematical part. For various reasons they were suddenly in doubt, however, that they had found the correct form of the theory.

The offer to join the Prussian Academy of Sciences in Berlin, combined with a chair at the Friedrich-Wilhelm University, was the provisional climax of this part of his career. In this context it is remarkable that in the proposal to offer the membership of this institution to Einstein it is stated that his earlier light-quantum hypothesis should not be held against him too severely.

Einstein moved to Berlin in spring of 1914. On the occasion of his inaugural lecture at the Academy in July, his mentor Max Planck introduced him by acknowledging the outstanding scientific merits of Einstein but did not hesitate to question his then most recent work on General Relativity. For the second time, Einstein experienced a strong opposition against his innovative scientific ideas and the corresponding conclusions. Amazingly, the opinion of the scientifically most prominent colleagues concerning his light-quanta idea did not even change when Robert Millikan, in 1916, achieved an exact experimental verification of Einstein's law of the photoelectric effect mentioned above. Although Millikan himself had to admit the perfect matching between theory and experiment, he still didn't believe that Einstein's explanation made sense. He even claimed that to his knowledge, Einstein himself no longer believed in the validity of his explanation of the effect. Of course, this opinion was completely unsubstantiated.

In Berlin, after an exhausting intellectual struggle, Einstein finally succeeded in formulating the General Theory of Rel-

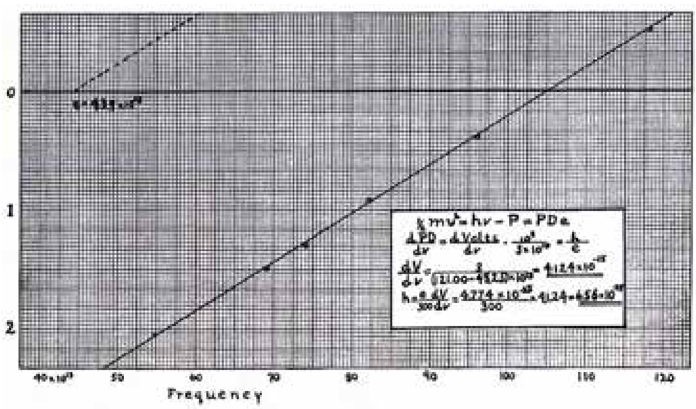

Fig. 2: Result of Robert Millikan's experimental determination of Planck's constant h. The diagram reveals the exact agreement with the law of the photoelectric effect (from Phys. Rev. VII, 355 (1916).

ativity and Gravitation in November 1915. The theory used mathematical tools that were not widely known at the time and therefore, only a few specialists were able to appreciate its content. One of the predictions dealt with the deflection of light rays by gravitational centres, i.e., masses. This phenomenon was verified in 1919. After the end of World War I, specially arranged astronomical expeditions of British teams under the auspices of the Royal Society in London set out to measure the deflection of star light by the sun during an eclipse. The collected data were claimed to quantitatively confirm the theoretical prediction and the result made a headline in the British newspaper *The TIMES* in November 1919. In this way, Einstein gained world wide prominence over night. Nevertheless, in spite of about 60 nominations over the years, he still hadn't achieved the status of a Nobel laureate. A growing number of prominent members of the scientific community expressed their amazement and it was felt that the situation became increasingly embarrassing for the Nobel Committee. The reasons for this situation are complex and are mentioned here only superficially.

According to the last will of Alfred Nobel, each year the Prize should go to persons whose accomplishments in the disciplines Physics, Chemistry, Medicine, Literature, the pursuit of Peace and, later added, Economics, has conferred the greatest benefit to mankind. Considering this condition, it seems then quite natural that accomplishments in theoretical and mathematical physics, Einstein's principal fields of activity, are difficult to judge in this respect and may not get elected to be awarded. These difficulties in connection with the Physics Prize are somewhat reflected in the fact that the responsible committee chose to postpone or even skip the award in several years between 1915 and 1920. The latter happened in 1916. In several of the following years up to 1921, the allocation of the prize was first postponed and finally awarded later. Only Charles Edouard Guillaume (1920) and Niels Bohr (1922) obtained the prize in the regular cycle. In the case of Einstein, the committee decided in November 1922 to bestow the prize to him for 1921 by honouring his contributions to theoretical physics in general and, in particular, his discovery of the law of the photoelectric effect.

In September 1922, Einstein was, in a subtle way, alerted that he might get the award later in the year. In a letter, the Nobel committee member Svante Arrhenius asked Einstein to save the time for a visit to Stockholm in early December but added that an official invitation was not to be expected before the 9 November. At the time, Arrhenius was aware that Einstein was planning a longer excursion to Japan and asked him to revise his travel plans. For various reasons, Einstein did not intend to change his plans and, in his return letter, informed Arrhenius to this effect. Nevertheless he expressed his hopes that the invitation would only be postponed and not altogether cancelled.

Together with his wife, Einstein left Berlin on 3 October 1922 and traveled via Zurich and Geneva to Marseille where on 6 October, they boarded the Japanese steamship SS Kitano Maru. On their sea travel they passed the Suez canal and headed, via Colombo, Singapore, Hongkong and Shanghai on to Kobe. On 10 November they reached Shanghai where Einstein, via telegram, was informed that he was chosen to receive the 1921 Nobel Prize for Physics and any further information would be transmitted by letter. Although it is quite certain that this news pleased him very much, it is not mentioned in his otherwise quite detailed travel diary. In a further letter dated 11 December and sent to an address in Japan, he was also informed about some details of the financial aspects of the prize. Einstein responded to these informations by a short letter to Arrhenius only on 10 January 1923. At the time he was already on his return travel back to Europe in the region of Singapore. The letter was written on stationary of the SS Haruna Maru. One sentence of this letter reflects Einstein's feelings with respect to his being awarded with the Nobel Prize in an amusing style: „*I am very glad to have received the Nobel Prize – also because there is no longer any reason for people to ask me the accusing question: Why don't you get the Nobel Prize? (My usual answer is: Because it is not I who can award the Prize)*". Along his return, Einstein also payed short visits, each lasting a few days, to Israel and Spain.

Arrhenius responded to that letter on 17 March. He informed Einstein that the insignia of the Prize in the form of a gold medal and a certificate had been received by the German ambassador in Sweden on the occasion of the regular festivities on 10 December in Stockholm [1]. In addition he suggested to organize a special reception event for Einstein during a grand Scandinavian exhibition in Gothanburg on the occasion of the 300th anniversary of this city. There Einstein would deliver a lecture which would be attended by the

1 after Einstein's return to Berlin, the medal and the certificate were delivered to him personally by the Swedish ambassador in Germany Baron Ramel.

Fig. 3: Certificate of Einsteins's Nobel Prize

Fig. 4: Einstein's delivery of his „Nobel lecture" in Gothanburg in July 1923.

Swedish King Gustav V. This is indeed what happend on 11 July 1923. Since the Lecture was not delivered on the occasion of the usual Nobel Prize ceremony, the topic was not on the discovery for which the Prize was awarded. Instead, Einstein chose to speak on "*Grundgedanken und Probleme der Relativitätstheorie*".

By covering the story of Einstein's Nobel Prize, a brief comment on its role in connection with the divorce of Einstein from his first wife Mileva Maric is in order. Mileva and Albert got married in January 1903 in Bern. Since summer 1914, she and their two sons Hans Albert and Eduard lived in Zurich, separated from Albert in Berlin [2].

On 31 January 1918, Albert had asked Mileva for the second time to submit a libel for divorce with him as the guilty part and, as encouragement, offered her some financial advantages. In order to secure the financial support of his former family, he offered her to receive the prize money of the Nobel award, should he ever be the recipient, Following a series of letters back and forth during the first half of 1918, as an advance measure, Albert deposited 40'000 Reichsmark (RM) in securities with the Schweizerische Bankverein in Zurich and an additional 20'000 RM with a Bank in Berlin, both in favour of Mileva if she agreed to a divorce. At the same time he requested Mileva to now submit the libel for divorce and to send him a draft of the divorce agreement that they had discussed previously. In early June this finally resulted in a draft of the document to which both sides agreed. At the beginning of November, Albert agreed with the suggested modus of payment but, for the first time mentioned his hope that his financial capabilities would not suffer too much in the aftermath of Germany's lost war.

On 14 February 1919, the trial before the Bezirksgericht Zürich, also attended by Albert, took its course and the divorce was officially executed. The financial aspects were part of the decision. Important in this respect was the deal that Mileva had no direct access to the deposit without the consent of Albert but was entitled to use the interests.

In the course of 1919, the exchange rate of the Reichsmark with respect to the Swiss Franc worsened dramatically. On 15 October, Albert informed Mileva that he could no longer meet the contractually agreed money transfers in Swiss currency. His somewhat unrealistic suggestions of how to solve the problem were, after some fierce intervention by Mileva, postponed for the time being.

The problem was finally solved when, as described above, Einstein indeed received the Nobel award. The prize money of 121'572.54 Swedish crowns was transferred to a special account with the Enskilda Bank in Stockholm on 11 December 1922, while Einstein was still in Japan. At the time this amount represented the equivalent of approximately 49 annual salaries of Einstein in Berlin! In order to avoid exchange-currency losses, the money was finally deposited with Banks in Zurich and New York. The former amount was later used to buy an apartment house in Zurich. The expected rental income was to secure the living costs of Mileva and their two sons.

Viewed in this light, the allocation of the Nobel Prize 1921 was not only a well deserved recognition of the scientific achievements of Einstein. It also prevented his threatening financial ruin and the prize money secured the financial support for his former wife and, his main worry, for his children and their education.

The content of this article is based on information taken from volumes 2, 8B, 9 and 13 of the **Collected Papers of Albert Einstein** (CPAE), published by Princeton University Press and the book of Abraham Pais, „**Subtle is the Lord**...", The Science and Life of Albert Einstein, first published in 1982 by Oxford University Press.

2 in the course of their separation in 1914, Mileva refused to agree to a formal divorce.

Pre-Announcement: Albert Einstein Symposium 2022

It has by now become a tradition that the SPS organizes a symposium between its annual meetings. The symposium commemorates an important event or person in the history of physics. After Richard Feynmann (2018), Georges Lemaître (2019) and Wilhelm Conrad Röntgen (2020/21) the 2022 symposium is planned to celebrate the centenary of the Nobel Prize for Albert Einstein.

In November 1922, it was announced that Einstein receives the Nobel Prize of 1921. The prize was awarded to him "for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect." So interestingly, there is no mentioning of both the Special and the General Theory of Relativity; rather the main reason given for honoring Einstein is his 1905 explanation of the photoelectric effect. It took more than 10 years to experimentally confirm Einstein's bold hypotheses. Einstein was not able to come to the award ceremony in Stockholm and only received the prize in July 1923 at a meeting of the Nordic Assembly of Naturalists in Gothenburg.

Since Einstein was mainly awarded the prize for a paper that he had written during his "*annus mirabilis*" when living in Bern, the symposium will take place in Bern:

9 April 2022, 10 – 17h
UniS, Schanzeneckstrasse 1, 3012 Bern,
Lecture hall S003

The symposium will start with providing the historical background and then move to modern developments of photonics.

The detailed program will be published on the webpages of SPS, SCNAT, and the Albert Einstein Society Bern (both our co-organising partners), as well as in the next issue of the *SPG Mitteilungen*. Please save the date for this exciting event!

Claus Beisbart, Chair of the HoPP Section