Werner Heisenberg and Albert Einstein

The Harvard community has made this article openly available. Please share how this access benefits you. Your story matters

<table>
<thead>
<tr>
<th>Citation</th>
<th>Holton, Gerald. 2004. Werner Heisenberg and Albert Einstein. Working paper, Department of Physics, Harvard University.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Published Version</td>
<td>10.1063/1.1292474</td>
</tr>
<tr>
<td>Citable link</td>
<td><a href="http://nrs.harvard.edu/urn-3:HUL.InstRepos:37852648">http://nrs.harvard.edu/urn-3:HUL.InstRepos:37852648</a></td>
</tr>
<tr>
<td>Terms of Use</td>
<td>This article was downloaded from Harvard University’s DASH repository, and is made available under the terms and conditions applicable to Other Posted Material, as set forth at <a href="http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA">http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA</a></td>
</tr>
</tbody>
</table>
24 March 04

Werner Heisenberg and Albert Einstein

Gerald Holton

To understand better Heisenberg’s enormous talent and his responses to the challenges of history, it is useful to examine his deeply significant relationship with another major scientist.

Being captured by Einstein

At the center of this case are Heisenberg and Albert Einstein. My interest in their interaction was aroused at a December 1965 UNESCO conference on Einstein’s work, where I had a first, accidental encounter with Heisenberg himself. I had been invited to lecture on Einstein’s epistemology, focusing on his pilgrimage, from an early positivism, strongly influenced by Ernst Mach, to what he called a “rationalism.”¹ I had followed that change in Einstein’s thoughts through reading his correspondence in the files, as described in Chapter 2.

On finishing my lecture, I left the podium, the next speaker came forward, and we met midway. It was Heisenberg. In passing, he whispered to me, “We must talk afterwards.” I shall return to this encounter later.

Among the main sources for what follows are Heisenberg’s eloquent books and autobiographical articles, the unpublished transcripts of the twelve interviews he gave to the History of Quantum Mechanics Project, his unpublished letters to Einstein, and some

thoroughly researched biographies. From these it emerges that in the history of modern physics no one but young Werner was so destined by the fates to be captured by Einstein’s relativity theory. In his *Gymnasium* days, he read and loved Einstein’s newly published popular book on special and general relativity. He would have been not quite eighteen when he heard of the sensational November 1919 eclipse expedition results. At the University of Munich, where he studied under the guidance of Arnold Sommerfeld, he attended Sommerfeld’s lectures on relativity. Heisenberg was also captivated by Hermann Weyl’s book, *Raum-Zeit-Materie*. To top it off, one of his closest friends in Munich was Wolfgang Pauli, who, while still a fellow student, was writing his *Handbuch* monograph on relativity theory. When Heisenberg moved to the University at Göttingen, he got more relativity theory from Max Born. In short, it came to him from all sides. Although Pauli wisely warned him to devote his future research to quantum physics instead of relativity, there was no way Heisenberg could escape being fascinated by Einstein’s work.

In his years at Munich University, Heisenberg went with some friends on a long bicycle tour around Lake Walchensee. At one point, while they were resting, the talk turned to Sommerfeld’s relativity course. Heisenberg was especially struck by a remark from friend Otto Laporte, recalling it later as follows:

“We ought only to use such words and concepts as can be directly related to sense perception….Such concepts can be understood without extensive explanation. It is precisely this return to what is observable that is Einstein’s great merit. In his relativity theory, he quite rightly started with the commonplace statement that time is what you read on a clock. If you would keep to such commonplace
meaning of words, you will have no difficulties with relativity theory. As soon as a theory allows us to predict correctly the result of observations, it gives us all the understanding we need.”

This “instrumentalist” or “operational” view of Einstein’s method was quite common at that time, and for decades afterwards. As we shall see below, Laporte’s long-remembered praise of it laid the groundwork for one of Heisenberg’s key insights many years later, which changed physics forever.

In the summer of 1922, Sommerfeld arranged for Heisenberg to go to Leipzig, where Einstein was to give a lecture. It was to be Heisenberg’s first encounter with Einstein, but instead it turned into a surrealistic glimpse of things to come. As Heisenberg entered the crowded lecture hall, a handbill was forced on him, signed by the Nobel physicist Philipp Lenard and eighteen other German scientists. It contained a vicious attack on Einstein, whose theory, as Heisenberg recalled, “was said to be nothing but wild speculations, alien to the German spirit, and blown up by the Jewish press.”

Heisenberg was shaken by this political attack on scientific truth—so much that he didn’t even notice that the speaker on the distant platform was not Einstein but rather Einstein’s courageous friend and colleague Max von Laue. Einstein had decided not to come, knowing that he was in mortal danger from Nazi rowdies.

**Only the Theory decides**

The first real meeting between our two protagonists occurred in 1924, when Einstein—at age forty-five about twice as old as Heisenberg—came briefly to Göttingen.

---

3 Ibid., p. 67.
The recent work of Bohr, Kramers and Slater—the BKS theory—was hot news. But because it relaxed the requirements of strict causality and of energy and momentum conservation, Einstein wrote to Max Born that if this kind of science would persevere, “I would rather be a shoemaker or employee in a gambling casino than a physicist.”

Against that background, Einstein and Heisenberg had a private talk in 1924, during a walk through the neighborhood. (By the way, what has happened to the life of scientists? Where have all those walks gone?) But, as Heisenberg, a proponent of Bohr’s point of view, immediately wrote to his parents, “Einstein had a hundred objections.” Coming from a scientist whose work Heisenberg had been admiring since early youth, this rejection of the new way of doing physics must have been difficult. But he consoled himself, as he said in one of his later interviews, that his generation, having “grown up into a complete mess” in quantum physics, was in the happy position of being able to give up old schemes if necessary.

On September 25, 1925, Heisenberg published in the Zeitschrift für Physik his brilliant breakthrough to quantum mechanics, “On the Quantum Theoretical Reinterpretation of Kinematic and Mechanical Relations.” He had arrived at it during two lonely weeks on the island of Helgoland, to which he had fled to recover from hay fever. The abstract of the paper announced Heisenberg’s fundamental guiding principle: to restrict oneself to observable properties of a spectrum, eschewing models built on unobservables such as the position and periods of electrons in the atom. As he put it, “This work is an attempt to find foundations for a quantum-theoretical mechanics which is based exclusively on relations between quantities that are in principle measurable.”
Heisenberg later observed that his crucial insight was an echo from the days when he had been struggling with relativity theory at the University in Munich. In his work leading up to that 1925 paper, he remembered the philosophy presented as Einstein’s viewpoint by his friend Otto during that bicycle tour: “regard only the observable magnitudes as the indication of atomic phenomena.”

But if Heisenberg had any illusion that his article would be approved by Einstein, he was wrong. One of Heisenberg’s five surviving letters in the Einstein archive, dated November 30, 1925, is evidently a reply to a note from Einstein (now lost) that had contained many objections. In his response, Heisenberg tried to hold out the hope of an eventual peaceful bridging between Einstein’s theory of light quanta and what he called “our quantum mechanics.” Heisenberg also drew prominent attention to his having used only “observable magnitudes” in his theory. All to no avail.

The following year, 1926, is one of high drama in this growing but troubled relationship. In April, Heisenberg gave a two-hour lecture on his matrix mechanics in von Laue’s famous physics colloquium at the University of Berlin. In the audience, with a whole group of potentates, was Einstein. It was their second meeting. Einstein, interested and no doubt disturbed by the lecture, asked Heisenberg to walk home with him (there is that walk again) and thus ensued a remarkable discussion, which Heisenberg first reported in print in 1969.

In the discussion with Einstein, Heisenberg once more tried to draw attention to his having dealt not with unobservable electron orbits inside atoms, but rather with observable radiation. He reports having said to Einstein: “Since it is acceptable to allow into a theory only directly observable magnitudes, I thought it more natural to restrict

---

4 Ibid., p. 88.
myself to these, bringing them in, as it were, as representatives of electron orbits.’

Einstein responded, “But you don’t seriously believe that only observable magnitudes
must go into a physical theory?” Heisenberg goes on, “In astonishment, I said, “I thought
that it was exactly you who made this thought the foundation of your relativity theory…..’

Einstein replied, ‘Perhaps I used this sort of philosophy; but it is nevertheless nonsense
(Unsinn)’.” And then came Einstein’s famous sentence: “On the theory decides what
one can observe.”

All this must have come to Heisenberg as a scathing attack on what he regarded
as his fundamental orientation, derived from reading Einstein’s early works, and being
guided by them from the start, right through his most recent triumph. Einstein, whose
development away from positivistic instrumentalism had escaped Heisenberg’s notice,
goes on to explain at length how complicated any observation is in general, how it
involves assumptions about phenomena that in turn are used in theories. For example,
one almost unconsciously uses Maxwell’s theory when interpreting experimental
readings involving a beam of light.

Perhaps this discussion helped Heisenberg eventually to embark on his own
epistemological pilgrimage, which ultimately ended with a kind of neo-Platonism in the
description of nature through the contemplation of symmetries. But in 1927, just before
starting on his next breakthrough—later called the uncertainty principle paper—
Heisenberg suddenly remembered Einstein’s provocative statement, “Only the theory
decides what one can observe.” It was a key to Heisenberg’s advance. As he put it later
in one of his interviews, “I just tried to turn around the question according to the example
of Einstein.”

5 Ibid., pp. 91-92.
At this point I should pause briefly to return to the unfinished story of my own encounter with Heisenberg in 1965. After giving his lecture, Heisenberg came over to tell me in detail about that 1926 meeting with Einstein, and what it had meant for him—all this four years before he published anything about it. Indeed, as if to make sure I had it straight, Heisenberg followed up by sending me a letter in January 1966, in which he repeated the account, and added a rather striking conclusion: While the theory determines what can be observed, the uncertainty principle showed him that a theory also determines what cannot be observed. Ironically, Einstein, through his 1926 conversation, had provided Heisenberg with some genetic material for the creation of the uncertainty principle article of 1927.

Descending along two tracks

We can now follow the effect of Einstein on Heisenberg along two diverging tracks. Both start at a high level, but descend eventually into terrifying terrain below. One track is the scientific one. Despite all his misgivings, Einstein of course realized the brilliance of Heisenberg’s work. He nominated Heisenberg for a Nobel Prize for three years before Heisenberg was so recognized, even though Einstein to the end believed that Heisenberg’s way of doing physics would ultimately turn out not to be true to the thoughts of the “Old One,” the Creator.

The third meeting of the two men took place in October 1927, at the six-day-long Solvay Congress of physicists in Brussels. That Conference was the scene of famous debates, mainly between Einstein and Schrödinger on one side, and Bohr, Heisenberg and
their like-minded colleagues on the other. It soon became clear that the Copenhagen spirit had triumphed. Day after day, Einstein presented ingenious arguments, which Bohr then answered before nightfall, until Paul Ehrenfest finally said, according to Heisenberg, “Einstein, I am ashamed for you.”

Heisenberg, in a later interview, added a shrewd point: “I would say that a change had taken place, which I can only express in terms of lawsuits. That is, the burden of proof was reversed…. That made a complete change of view among the younger generation…. ” Ironically, the same kind of reversal of fortunes had happened long before, in the triumph of Einstein’s relativity over his opponents. But Heisenberg’s last surviving letter to Einstein, written a few months before the Brussels meeting, already showed the cocky self-confidence of the victors in that new struggle. Heisenberg wrote there that while in the new quantum mechanics Einstein’s beloved causality principle was baseless, “We can console ourselves that the dear Lord God would know the position of the particles, and thus He could let the causality principle continue to have validity.”

Strangely enough, in 1954, a year before Einstein died, Heisenberg sought out Einstein once more. Meeting with him in Princeton, Heisenberg found that Einstein’s view had not changed since the 1927 Solvay Congress. Despite all Heisenberg’s persuasive skills, Einstein just said, “No that’s nothing. That’s not the thing I am after. I don’t like your kind of physics. I think you are all right with the experiments…but I don’t like it.”

---

The second track that follows the later relation between the two men concerns the full emergence in Germany in 1933 of what from the mouth of the Beast had been forming since the early 1920s. For a time, Heisenberg continued to mention Einstein in his lectures and publications. But the scene was now dominated by demons, including the raving articles published by Johannes Stark, branding Heisenberg in 1935 the “spirit of Einstein’s spirit.” The published attacks on Heisenberg and on theoretical physics as such culminated on 15 July 1937, with an article in the official journal of the SS, Das Schwarze Korps. That article, endorsed by Stark, called Heisenberg a “white Jew,” and dismissed relativity and quantum theory as non-German, Jewish thinking.

There followed a one-year attempt by Heisenberg to obtain exoneration from Heinrich Himmler, head of the SS, who happened to be a family acquaintance. That effort finally succeeded, although with the stipulation that in the future Heisenberg would “clearly separate for your audiences, in the acknowledgment of scientific research results, the personal and political characteristic of the researcher.” Privately, Himmler had his eye on Heisenberg as a possible researcher on Himmler’s own crazy obsession, the “World Ice Theory,” of which more in Chapter 11. But any future playwright constructing a version of the Heisenberg-Einstein relation will not be able to avoid including the cries, off stage and ever more distant, of the unmentioned millions who had also loved their homeland, but had no way to make a deal with Himmler, or to bribe an SS man bent on murder.

*Recasting the portrait of Einstein*
At this point in the narrative, we are at last in peacetime, with Heisenberg securely installed as the leader of a new generation of German physicists—as he had hoped to be all along. But now, in two of Heisenberg’s lectures, we find passages that signal the depth to which his relationship with Einstein had fallen.

Shortly after Einstein had died in 1955, Heisenberg published a popular article entitled, “The Scientific Work of Einstein.”\(^7\) The essay began with a generous assessment of Einstein’s contributions, but then found a serious fault with him, namely “that Einstein, to whom war was hateful, should have been moved by the infamous practices under Nazism to write a letter to President Roosevelt in 1939, urging that the United States vigorously set about the making of atomic bombs...” which eventually “killed many thousands of women and children....”\(^8\)

That bitter statement was at the very least a major exaggeration. The famous letter of August 1939 that Einstein signed had been written just as the German war machine was poised to start its Blitzkrieg—and, as we now know, four months after Paul Harteck and Wilhelm Groth had asked the German War Office to investigate nuclear explosives. Far from urging that the United States vigorously set about the making of atomic bombs, Einstein’s letter was, in his own words, “A call for watchfulness and, if necessary, quick action,” not least because “Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over.”

The letter asked only to establish a liaison between the U. S. Government and the physicists, and for help to raise funds for experimental work in university laboratories, if necessary from private donors and industrial laboratories. The direct result was that all of


\(^8\) *Across the Frontiers*, p. 6.
$6,000 was made available to Enrico Fermi at Columbia University. Einstein declined the invitation to be a member of a group to coordinate further research.

Einstein signed a second letter to Roosevelt in March 1940, reporting that he had heard that research on the use of uranium was indeed going on in Germany; this letter, too, produced little action. In fact, the U. S. Government did not gear up seriously until October 1941 when it received the so-called Maud Committee report, with the conclusions of a British-sponsored study on how one might produce an atomic bomb.

Leo Szilard persuaded Einstein to write a third letter, in 1945, that was simply a letter of introduction to Roosevelt for Szilard, who was not allowed to tell Einstein the need for it. Szilard hoped to use this letter to convey to Roosevelt his doubts of “the wisdom of testing and using bombs.” But Roosevelt died before this plea reached him.

Einstein himself, now regarded as “unreliable” by the authorities, was carefully shielded from direct knowledge of the Allied nuclear project. This secrecy even resulted in a moment of comedy. In late December 1941, Vannevar Bush tried to get advice from Einstein on building uranium hexafluoride diffusion plants. But because Einstein was given only vague details, his reply was useless. Bush then was asked by the intermediary if Einstein could be given more information. Bush cried, no, don’t tell him one more thing, or he will guess the rest of the project, and might blab. The voluminous files the FBI kept on Einstein show that FBI director J. Edgar Hoover was personally devoted to having Einstein spied upon. It is ironic that on one side of the Atlantic, Heisenberg was called a “white Jew,” Einstein on the other side was considered by some to be a red one.

Heisenberg’s (1955) remarks about Einstein were not to be an isolated exaggeration. Heisenberg gave a second, more detailed attack on Einstein in June 1974,
when he spoke, of all places, in the so-called Einstein house in Ulm, Germany. As in 1955, he began with a generous survey of Einstein’s work on relativity. He then repeated some of the points made in earlier publications, including an account of Einstein’s rejections of Heisenberg’s theories.

But at that point, Heisenberg had to add something, “in order not to leave the portrait of Einstein all too incomplete.” Einstein, he said, “wrote three letters to President Roosevelt, and thereby contributed decisively to setting in motion the atom bomb project in the United States. And he also collaborated actively, on occasion, in the work on this project.”

[Editor: keep space]

If there is to be some day a play based on the relation between these two men, the playwright will perhaps note that these astonishing exaggerations, uttered in Einstein’s birth town, were part of a Heisenberg lecture with the title “Encounters and Conversations with Albert Einstein.” In that last talk, Heisenberg, two years before his death, had his final encounter with the person whom he had once called his Vorbild, his model; the person who for good and ill had unknowingly been the cause both of deep insights and of fierce insults throughout Heisenberg’s scientific and personal life; and whose acceptance Heisenberg had sought again and again, always in vain. Those rejections by Einstein, at each encounter, had evidently left on Heisenberg a bitter scar, which bled once again at that Einstein-house lecture. Niels Bohr, to his death in 1962, was also deeply saddened by Einstein’s constant refusal to accept his interpretation and program. And as to Einstein himself, he often cursed the quantum he himself had set

---

loose, only to have it haunt him in the form of a physics that he could not accept, one initiated largely by Bohr and Heisenberg.

In that future play, as the curtain falls on these three extraordinary men, even the evil spirit that has been watching them from the wings of the stage, and that had haunted the whole terrible century, will, in the end, have to shed a tear for humanity.

________.________