Oppenheimer and His Physics
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By David C. Cassidy ©

Among his many accomplishments, J. Robert Oppenheimer is probably best known for his staring role on the world stage of history as the atomic doctor, the scientific head of the Manhattan Project that built the atomic bomb. But he played other historical roles as well. He was for a time after the war the public personification of science, the government's inside authority on nuclear weapons, the nation's most public scientific victim of cold war McCarthyism. And during the 1930s–he was simultaneously the left-wing intellectual, Berkeley Bohemian, Sanskit linguist, and--by the way– a theoretical physicist.

Where did the physics come from? How is it that J. Robert Oppenheimer, the man of so many humanistic talents and pursuits, become one of the most influential theoretical physicists of his time? In what ways was he influential? And what did he actually do in physics? In attempting to answer such questions, I must of necessity be very brief and I will be mercifully non-technical.

The physics began to arise at Harvard from where, in 1925, he set off for Cambridge University following graduation in search of a doctorate in experimental physics.

A frustrating year of fumbling around in Cambridge physics laboratories gradually convinced Oppenheimer that experimental work was not his field. The only bright spot that year was his good fortune to have been in Cambridge at the birth of quantum mechanics. Shortly before Oppenheimer arrived in Cambridge, German physicist Werner Heisenberg had delivered a public lecture there on atomic spectra, as well as the private news to theorist Ralph Fowler and his student, Paul Dirac, that he had made what became the first breakthrough to quantum mechanics in the form of abstract matrix mechanics. Oppenheimer began attending lectures by the 2-year-older Dirac on the results of his efforts to help bring the new quantum mechanics to completion. Soon Oppenheimer was applying Dirac's work to practical problems under Fowler. By May 1926 he had his first two papers ready for publication. One of these, on the quantum mechanics of colliding electrons, interested another German visitor to Cambridge that year--Professor Max Born, who presided over the birth of quantum mechanics in Göttingen, Germany. Born was so impressed with the young American that he invited him to Göttingen for the coming year.

Oppenheimer jumped at the offer. "I felt completely relieved of the responsibility to go back into a laboratory," he wrote. "I hadn't been good, I hadn't done anybody any good, and I hadn't had any fun whatever; and here was something I felt just driven to try." It was for him another audition. But he easily landed the part and made it his own at stage center of the quantum revolution.

This same pattern repeated itself over the next two decades. Superiors who recognized his great talents encouraged his work and selected him for promotion up the professional ranks of theoretical physics. Soon it was the Americans who made the selection and they did so for a specific purpose: to bring American physics to the forefront of world research. Their strategy was 3-fold: to select a few of the very best physics postdocs for advanced training in quantum physics in Europe and the United States, 2nd to build up a few selected universities into elite research institutions, and 3rd to place their proteges in key teaching positions at those universities, where they would create research schools to rival the Europeans.

Oppenheimer became a favorite candidate for this strategy when American recruiters came to Göttingen in search of talent--and it continued right through his selection to head the Manhattan project 17 years later.

The once fumbling Oppenheimer completed his doctorate under Max Born within months of his arrival in Göttingen in Fall 1926. His dissertation, which he published in a German physics journal, was on the quantum mechanics of continuous spectra emitted by atoms and accelerated charges. Several other papers utilizing the new quantum mechanics quickly followed. One of these contained the famous Born-Oppenheimer approximation for calculating the properties of molecules.

Again, a pattern was set. Oppenheimer eventually published 12 research papers while in Göttingen and in subsequent European locations before settling in California in late 1929. All were marked by orginality, innovation, and complete mastery of the difficult mathematics of the new physics. But, being just 2 - 4 years younger than the creators of quantum mechanics, Oppenheimer had to settle mainly for applications of the new physics to explanations of old and new phenomena, rather than fundamental contributions to the new theory. His papers in that period included studies of the band spectra of molecules, the scattering of alpha rays, the polarization of scattered light, the capture of electrons by atoms, and the Ramsauer effect in spectroscopy.

With a doctorate in theoretical physics from Göttingen, Oppenheimer returned to the States in 1927 a hot commodity. Sponsored the National Research Council, or NRC, Oppenheimer split the 1927-1928 academic year between Harvard and Caltech. The following year, 1928-29, he went back to Europe as one of only 3 physics postdocs selected by the International Educ. Board of the Rockefeller Foundation. One of the other two was Isidor I. Rabi, who became a life-long friend. Working with Paul Ehrenfest in Leiden and Wolfgang Pauli in Zurich and visiting Heisenberg in Leipzig, Oppenheimer was fully prepared to bring what Rabi called the European "taste and style for physics" to American institutions. Rabi said: "Americans who had studied in Europe and came back...decided that there was no reason things like that shouldn't be going in this country, and we went to work on it."(p115)

And work on it they did. Oppenheimer returned to the States for good in August 1929 to begin teaching at the Univ of Calif. at Berkeley. At the request of Caltech's president, Robert A. Millikan, he agreed to spend a portion of each year working at Caltech in Pasadena. UC Berkeley was then one of the mediocre state colleges selected by Millikan and the NRC for transformation into an elite research institution, and Oppenheimer went there precisely for the opportunities it afforded. He was joined by another NRC fellow, the experimentalist Ernest O. Lawrence. Within a decade Oppenheimer and Lawrence succeeded in their mission to help bring California physics to the forefront of American and world research. During the 1930s, Berkeley and Caltech were two of the top 5 producers of American physics doctorates. (The others were Michigan, Chicago, and Cornell.) Together, Berkeley and Caltech accounted for 1/3 of all physics doctorates in the US during the 1930s, and they have remained among the leaders ever since.

Lawrence's Radiation Laboratory centered around his invention of the cyclotron in 1932. With massive funding from the Rockefeller Foundation, it became the early nucleus of the Manhattan Project and the model for post-war big science. Oppenheimer's theorists worked closely with Lawrence's big machine experimenters. In addition, every summer and during school vacations Oppenheimer and an entourage of 10 or so graduate students and postdocs migrated South to Pasadena to work with Cal Tech experimentalists Carl Anderson, Seth Neddermeyer and others on the mysteries of nuclei and cosmic rays. These collaborations were so successful that Oppenheimer's California School of theoretical physics soon did rival the European schools, as well as the many newly emerging American schools at selected eastern universities.

There were plenty of experimental discoveries for the theorists to work on, some occurring right in California. The so-called miracle year of 1932 alone brought Anderson's discovery of the positive electron at Caltech, the British discovery of showers of created particles in collisions of high energy cosmic rays, the discoveries of the neutron and the deuteron, Heisenberg's neutron-proton model of the nucleus, and Pauli's prediction of a new elementary particle, the neutrino.

But how successful was Oppenheimer's school, and what did he and it actually produce in physics? Upon closer look, it is evident that Oppenheimer was, in those years, neither a popular teacher nor an excellent bureaucrat. Students avoided his courses because of his high demands and poor teaching style. But, wrote Hans Bethe, for those who could follow him "he gave his students a feeling of the beauty of the subject, and he conveyed his excitement about its development."(155) Perhaps because of his demanding style, Oppenheimer did not produce a large number of doctorates–only 22 in the period from 1930 until he left for Los Alamos in 1943, and only 6 through 1939. During the same period, 1930-39, the entire department produced 70 doctorates. Oppenheimer's other 16 doctorates thru 1943 all graduated during the early 1940s, when the collaboration with Lawrence and his new accelerator were at their height. [3 others] He did not mentor any Caltech doctoral students, nor was he even listed as an examiner of any of the graduates.

During the California years, Oppenheimer authored or co-authored 36 research papers and 16 abstracts of conference papers. Most of his papers were aimed at unraveling data in nuclear and high energy physics. The papers covered such topics as the nuclear photoelectric effect, the theory of electrons and positrons, and the build up of cosmic ray showers through quantum electromagnetic processes.

Compared with similar research elsewhere at the time, Oppenheimer and collaborators did not always produce the most innovative work. Oppenheimer obviously had many other things on this mind at the time–as we know. But he and his students did produce solid work on the emerging problems of the day. And together with Lawrence's radiation lab, they helped form a solid foundation for the big-physics profession to follow during and after the coming war.

Perhaps Oppenheimer's greatest success in physics occurred with his school's most speculative and least experimentally driven work--that on the collapse of dying stars which led to the prediction of what are now called neutron stars and Black Holes.

On several occasions during the 1930s, Oppenheimer spoke in Pasadena on the application of nuclear theory to astrophysics, and he and his students began work on nuclear fusion as the source of the sun's energy. Unfortunately, just as they prepared to present their results in 1937, Hans Bethe published a full-scale theory of stellar energy, for which he received the Nobel Prize 30 years later.

Scooped by Bethe, Oppenheimer and his students were encouraged by Richard Tolman at Caltech to consider the application of nuclear physics together with general relativity theory, not to the flourishing of a star, but to its death -— the events occurring in the sudden collapse of a star in a cataclysmic explosion that we sometimes observe from earth as a nova, or supernova. Oppenheimer and his students discovered that stars about 1 ½ to 3 times the mass of the sun would collapse into what became known as a "neutron star," sort of a huge nucleus. For larger stars, they found that the pressure at the center of the collapsing star would become so great that it would be mathematically undefined, or infinite, in value–a mathematical singularity from which, they predicted, not even light could escape. John Wheeler later called it a Black Hole.

This was research of potential Nobel Prize quality. Unfortunately, it went nowhere. Mathematicians at the time avoided singularities even more than they do now, and observational astronomers were still trying to unravel the mysteries of galaxies, nebulae, and the expanding universe. The study of black holes did not take center stage until the evidence for their existence began to mount during the 1990s with the vistas opened by the Hubble Space Telescope.

Oppenheimer returned to Berkeley after the war, where he mentored his last three doctoral candidates. At the same time, he continued his role as the impresario of group efforts when he presided over the famous Shelter Island conference that enabled the advance of postwar high-energy quantum physics.

In 1947 he moved to Princeton as the director of the Institute for Advanced Study. During his tenure, the institute was heavily weighted toward physics and mathematics with the presence of such luminaries as Albert Einstein, John von Neumann, Hermann Weyl, and Kurt Gödel.

But Oppenheimer never again published a research paper in physics. Oppenheimer died in

Princeton of throat cancer in 1967, 2 months short of his 63rd birthday. Thank you.