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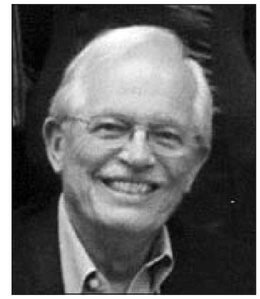

John J. Compton

Arthur Holly Compton: The Adventures of a Citizen Scientist

John J. Compton

Perhaps one never knows one's parents, really knows them. You never know their early lives and, as a kid, you are living inside your own skin, not theirs. Growing up in Chicago, I never knew my dad was famous. He was just a firm, affectionate, if too busy father figure, who loved music and the outdoors, played tennis better than I could, was awfully good with tools, and could explain scientific ideas so well that I almost understood them. I knew he was a physicist and taught at the University of Chicago, and he and mother often took me on lecture or research trips, but I did not know what it was all about. During the war, when he was one of those in charge of the bomb project and we had moved to Oak Ridge, he was just a hard-working ordinary man doing a war job like everybody else.

August 6, 1945, brought a dramatically different perspective. My father was suddenly a national and world figure. That fall, as I went off to college, I began to hear something of his achievements—not only the bomb, but the cosmic ray studies and the Nobel Prize, with all that they seemed to entail.

That history has been an aura surrounding me ever since. Of course, this was, and is, a matter of much pride; it was also a source of misgiving. My father preceded me everywhere—the unacknowledged "elephant in the room" that opened doors and created expectations. I had to prove myself, all by myself, and I managed to find my own path. But, as I have thought back about it, I seem to have done so in two almost contradictory ways. It is evident to me now that I never did leave my father behind—the issues of his later life, as an interpreter of the philosophical import and social impact of the sciences, became my issues too, and we often had vigorous discussions about them. In this way, he was surely the reason for my going into philosophy. On the other hand, in spite of that inheritance, I have come to see how much of my father remained hidden from me. Perhaps, out of self-preservation or preoccupation, I did not look closely enough. In any case, I see now how little I ever really knew of what he achieved. What follows is something of what I have come to know of my father's remarkable career. I have called it "The Adventures of a Citizen Scientist," because his life was truly one adventure after another, propelled by his love for scientific discovery and his desire to be of service to the nation and to humankind.

I

The most powerful evidence of this, of course, came during World War II. In August of 1939, shortly after word reached this country about German work on uranium fission, Leo Szilard got Einstein to send his famous letter to President Roosevelt sounding the alarm. It explained the military possibilities of fission and warned that the Germans were aware of them too. However, responses to the letter by presidential advisors did little to advance the research needed to determine whether atomic energy was likely to be of any use to America in the coming war. Individual scientists were at work in their universities, to be sure, many of them European emigres anxious about the Nazi threat. But there was no high-level government office to coordinate scientific research and development; there was no National Science Foundation, there were no national laboratories. Citizen scientists had to step up. And since its

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founding, the National Academy of Sciences was the place to find them.

In June 1940, after the fall of France, at the urging of Arthur Holly Compton and his colleagues in the Academy, President Roosevelt created a new governmental entity, called the National Defense Research Committee (NDRC), and named Vannevar Bush, formerly of MIT, as its chairman. Then in April of 1941, Bush asked Compton to chair a special committee from the National Academy—of both engineers and scientific people—to appraise the possible military value of atomic energy.

At the outset, there was universal agreement in the group that uranium fission would eventually prove to be an important source of energy to generate electricity and possibly to power ships and submarines. But, given the scientific and technical uncertainties and the immense anticipated cost of separating the rare, fissionable U-235 from tons of the common U-238, very few believed that it was likely to have any immediate use as a weapon of war. It was Ernest Lawrence, from the University of California, who changed the NDRC's thinking. The new element plutonium (P-239) had recently been discovered in his laboratory, produced from the widely available U-238. Like U-235, it was highly fissionable. By producing plutonium in a large, controlled reaction uranium pile, one could make enough—as little as 100 or so pounds would do—to make a powerful bomb. Lawrence met with James Conant and Compton in our house in Chicago in September of 1941, and, with this new possibility in mind, they determined to urge their National Academy committee to move quickly.

Compton consulted with Enrico Fermi at Columbia and Eugene Wigner at Princeton—they were convinced that the chain-reacting pile would work, and Compton confirmed their calculations. Thanks to Harold Urey's research, new possibilities for large-scale separation of U-235 emerged as well. Whether one used plutonium or uranium, the engineering challenges were going to be daunting. But by late November, the committee was unanimous. They were ready to recommend to Van Bush and the NDRC that a full-scale effort be launched to make an atomic weapon. It might, they said, determine the outcome of the war. Compton delivered their report on November 27, 1941. The NDRC approved it, Bush took it to President Roosevelt, and on December 6, after consulting with his advisors, the president gave the go ahead. The next day, we were in the war.

The task of developing the plutonium option was put into Compton's hands. And in the fall of 1942, as the army was put in overall control, Compton sought out Robert Oppenheimer to manage the actual bomb construction at Los Alamos, while he gathered the remarkable group of scientists, engineers, and cooperating industrial people, centered at Chicago, in what came to be called the "Metallurgical Laboratory"—later extended to Oak Ridge and Hanford, Washington—that was to explore the fission science and invent the massive technology necessary to produce the plutonium raw material. The uranium option was to be pursued as well. In his National Academy report, Compton had made some estimates of how long it might take to actually come up with a working weapon—between three and five years, he said. The actual time from December 6, 1941, to August 6, 1945, was three years and eight months.

By now, the story is familiar; it has been told by one author after another. The immense scientific, engineering, and industrial challenges were met and the bomb was created and used. In 1956, Compton wrote his own book about it—he called it *Atomic Quest*, and for him that was what it was. In a time of world war and national crisis, he was proud to have been a part of the effort to secure atomic weapons and atomic energy for the United States. To him as a scientist, however, the most decisive moment, among many along the way, was the dramatic experiment that showed that a controlled, nuclear chain reaction was indeed possible and, thus, that the effort to employ such a reaction to produce plutonium on a large scale could proceed.

The experiment was to take place in an abandoned squash court under the west stands of Stagg Field, the University of Chicago stadium (now torn down and replaced with a handsome library). There was a problem, though—for obvious security reasons, Compton could not ask the president of the university, Robert Maynard Hutchins, for authorization to put the critical experiment on the campus. He had to make the decision himself. An attempt was going to be made, for the first time in history, to liberate energy from the atom in a controlled manner. It could quite possibly fail to work. Or worse: if the reaction were to go out of control, it could result in a disastrous explosion—in the middle of the city of Chicago.

It was a shocking plan, acceptable only from a sense of great urgency to get on with it. But "the Italian navigator," Enrico Fermi, the genius behind it, had carefully calculated what would happen and was confident that the danger was minimal. He and his scientific crew had for weeks been building the reactor pile, brick by graphite brick, around the uranium core. Cadmium-coated control rods, inserted in the pile, prevented the reaction from taking off. When they were withdrawn, the graphite should capture just enough of the uranium's escaping neutrons to allow the process of fission to go on, but slowly. Compton checked the calculations himself. It was the morning of December 2, 1942. You need to hear Compton's own description of what happened next:

> We entered onto a balcony at one end of the squash-court laboratory. At the opposite end of the room was the massive pile of graphite blocks, within which the uranium was embedded. On the balcony with us were twenty others, including Fermi. Most of these were engaged in making various adjustments and reading a variety of meters. On the floor below was George Weil, whose task was to handle the control rods. On a platform over a corner of the pile was a group of three men whom we jokingly called "the suicide squad." It was their responsibility, in case the reaction could not otherwise be stopped, to throw buckets of cadmium solution over the pile. Norman Hilberry was ready with an axe to cut the rope holding a safety rod if the reaction should begin to grow with sudden violence. The door to the balcony was through a concrete wall. A hundred feet further back, behind a second concrete wall, was another group of men, following the course of the experiments by remote control instruments and an intercommunications system. It was their task, if something should happen to those of us in the laboratory beside the reactor, to throw in the "safety rods" by remote control.
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> Fermi was conducting a systematic series of experiments, reading the meters as the final control rod was drawn out step by step. The results he plotted against his predictions. The data fitted his calculated line with remarkable precision, showing that as the critical condition for the sustained chain reaction was being approached no detectable new phenomenon was affecting the results … It was the middle of the afternoon before the preliminary tests were completed. Finally Fermi gave Weil the order to draw out the control rod another foot. This we knew meant that the chain reaction should develop on an expanding scale.
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> The counters registering the rays from the pile began to click faster and faster until the sound became a rattle. I was watching both a recording meter and a galvanometer. I could see the light from the galvanometer begin to move across the scale. The line traced by the recording stylus was now curved upward. Finally after many minutes the meters showed a reading that meant the radiation reaching the balcony was beginning to be dangerous. "Throw in the safety rods," came Fermi's order. They went in with a clatter. The spot of light from the galvanometer moved back to zero. The rattle of the counters died down to an occasional click. I imagine that I can still hear the sigh of relief from the suicide squad. Eugene Wigner produced a bottle of Italian wine and gave it to Fermi. A little cheer went up. Atomic power! It had been produced, kept under control, and stopped.[1]

I have heard that story many times. But what amazes me still is not only the achievement of that first controlled reaction, but the fact that Fermi predicted and tracked it with such confidence, and that Compton could, with similar confidence, have calculated that the danger of its turning catastrophic was so slight that he could risk blowing up an entire city.

There was another decisive moment, during one of our rare family vacations in Michigan, when Robert Oppenheimer came to see Compton with the awful anxiety that an atomic explosion might actually fuse atoms of hydrogen in the water, or nitrogen in the air, and engulf the entire globe in a conflagration. He and his team (including Edward Teller) had discovered the principle of the fusion bomb. They almost stopped the entire project in its tracks, until further calculations showed that, under the conditions they envisioned, this horrific outcome would be beyond any reasonable probability. But what an incredible decision to have to make! How could you trust such calculations? How could you trust yourself? Only, I think, through a kind of faith embedded in science itself. Only if you were part of a long history of experimental work, only if you were someone who had seen, again and again, that the physical world does follow precisely calculable, mathematical laws—and you had strong evidence that you knew what those laws were—could you confidently risk these things. From the time of Newton until the present space age, this is just what being a physicist has meant.

II

It is worth asking, though, what was it in *his* particular history that prepared Compton for this kind of wartime leadership position? For an answer, one has to go back to the decade before the war—to a time when the largest laboratory for studying elementary physical forces and particles was not in some university building, but in the air around us, where strange, high-energy radiation was coming into the earth's surface from outer space. In 1912 in Austria, Victor Hess was the first to identify this radiation when he found his electroscope discharging more rapidly as he ascended in a balloon. No one knew what it could be, and it soon became a focus of international study.

Robert Millikan—then probably America's most eminent physicist—framed the first theory of the origin of this new radiation, which he dubbed "cosmic rays." He called them "the birth cries of the stars," and proposed that they were high-energy light photons, emitted in interstellar space when simple atoms, like hydrogen, fused together to fashion the heavier ones which would, eventually, coalesce into the large celestial objects we see. But there was some counter-evidence to this. A Dutchman, Jacob Clay, found different intensities of cosmic rays at different latitudes, with decreasing intensity near the equator, suggesting that the rays, unlike photons, had electrical charge and were being affected by the earth's magnetic field. As the thirties began, however, Millikan's view prevailed and, according to his own measurements, it seemed to be confirmed.

Enter Arthur Compton, another student of radiation. The enormous penetrating power of some of these incoming rays—with energies far in excess of those normally associated with photons—seemed to him to argue for the charged particle hypothesis. So did Luis Alvarez and Tom Johnson's measurements in Mexico—their results showed that there was a directional effect, more rays coming from the West than the East, which is just what should happen if the rays were positively charged. In order to get a definitive answer to the problem, Compton determined to launch a systematic, world-wide survey of cosmic ray intensities at differing latitudes, from Antarctica across the equator to the Arctic, in every hemisphere, East and West, up the highest mountains and down in the deepest mines. Supported by a grant from the Carnegie Corporation, he organized nine groups of researchers, some headed by his graduate students or colleagues at Chicago, others by colleagues in Mexico, Denmark, India, and South Africa. They were determined, as he put it once, to "decode the mystery of cosmic rays."

It was the scientific adventure of the age—and the largest group of scientific researchers that had ever been assembled on a common project. Why did Compton have the experience to imagine the much larger "atomic quest" later on? Because he had managed this one, what *Time* magazine later called his "cosmic quest." Over a period of two years, the teams covered the globe, packing their ionization chambers and electrometers with them. It was in the name of science, to be sure, but it was equally Indiana Jones—with all its risks. Although they secured the best high-altitude measurements of any, two members of one team lost their lives while climbing on Mt. McKinley in Alaska.

Compton himself climbed Colorado's Mt. Evans, flew in a plane inside the Arctic Circle, and led a group, on pack horse, into the high Andes of Peru and the Himalayas in India. My mother and elder brother went with him on many of these trips, sharing the duties of instrument reading—although I, at the tender age of 4, was left behind. In the course of all his travels, Compton crossed the equator five times. He sent a ship around Cape Horn and put Admiral Byrd in charge of measurements in Little America, and he commissioned a deck officer on a ship of the Canadian-Australasian Line, the HMS *Aorangi*, to carry his instruments from the Northern Pacific, past Hawaii, all the way to Australia and New Zealand.

There was another, lesser but no less fascinating, adventure lodged within this one. In 1932–1933, as the world survey results began to come in, Compton's position appeared to be supported more and more strongly. There was nearly a 20% variation in cosmic ray intensity from the equator to the poles. Nonetheless, Millikan thought these numbers were inconclusive. His view was that there might well be charged particles near the surface of the earth, but that they were only "secondary radiation," the product of his photons' impact on particles in the atmosphere. If only one could get well above the atmosphere, one could tell! Millikan had been sending his own equipment up in airplanes to see whether this secondary radiation fell off with altitude, albeit with only modest success. The debate between the two scientists was played out in several tense scientific meetings and in the press. Cosmic rays had popular appeal.

Just at this point, the officials planning for the upcoming Chicago World's Fair had an inspiration. They had already contracted with August and Jean Piccard, the Swiss brothers who had pioneered stratospheric balloon flight in Europe, to attempt an ascent during the World's Fair, highlighting the Fair's grand theme, "A Century of Progress." What better strategy than to invite Compton and Millikan to put their competing electroscopes in a new gondola and balloon, this time made in America, and send it up, hoping for a new high altitude record and for cosmic ray measurements that would resolve the famous debate? This would show the world how far American science and technology had come![2]

Dow Chemical Company was enthusiastic about showing off its new lightweight magnesium alloy, "Dowmetal," for the gondola, and Goodyear-Zeppelin wanted to showcase its new rubberized cotton fabric for the balloon. Army and Navy aviators, who had been striving for altitude records themselves, were happy to cooperate as needed. There was even a rivalry with the Soviet Union—their balloonists were about to fly into the stratosphere too. Compton was delighted with the flight prospect and, although Millikan balked at first, he decided to go along. The press had a field day. The *Chicago Daily News* proclaimed, "The Piccard Flight May End Compton-Millikan Debate on Cosmic Ray Properties," and added that the celebrated debate "may be settled once and for all this summer, the cosmic ray itself acting as referee."[3]

When inflated, the Century of Progress balloon was taller than King Kong—more than 150 feet high. After a long night of waiting for last-minute adjustments, in the early morning of August 5, 1933, a huge crowd watched as the flight took off from the middle of the Fair, in Soldier Field. Because of a contract dispute with Fair officials, the Piccards had bailed out, and it was Air Force Major Thomas Settle at the controls. Then, to everyone's dismay, only twenty minutes after take off, the balloon came down in the nearby Burlington rail yards. Settle had had to abort because of a failure of a valve in the balloon vent control system. My mother always contended that, in the hasty descent, one of her precious down comforters, used for insulation, had somehow been thrown overboard, but the news accounts never confirmed her complaint! Another attempt, this one successful, was made in late November, but from Akron, Ohio, for by that time the Fair had closed. This second flight did in fact set a new altitude record—61,237 feet. Fair promoters touted the success and the aeronauts were paraded through main streets throughout the mid-West. But the pilots had not attended carefully enough to the scientific instruments, so the scientific rewards were of negligible value. The Compton-Millikan debate was not settled.

Over the next two years, however, as evidence from the world survey piled up, and as other investigators sent up smaller, unmanned balloons, showing that the latitude effect, far from decreasing in the upper atmosphere, actually increased by more than 90%, the scientific community moved decisively to the Compton side. Finally, on January 1, 1936, in a meeting of the Physics Section of the American Association for the Advancement of Science held in St. Louis, Compton wrote the concluding chapter to the drama.[4]

To a packed house, including newsmen, Compton recounted the long history of the investigation of cosmic rays and presented the overwhelming evidence that the primary rays were electrically charged corpuscles—predominantly protons and alpha particles, together with some positive and negative electrons. Directional measurements showed, he noted, a greater intensity of the radiation coming from the direction in which our Milky Way is moving relative to the stars, suggesting that Millikan was right that they come from the depths of space, but he rebutted the photon hypothesis point by point. Millikan attended the session, but made no comment. The January 13 issue of *Time* magazine put Compton on the cover and commented that "[Although] his was but one of a thousand discourses made last week, … for most of the audience it marked the end of the 'mystery' of cosmic rays, wrote finis to one of the most reverberating scientific controversies of the century."[5] Cosmic rays are still avidly studied today, chiefly to explore their detailed composition and their astro-physical origins—now thought to be within exploding supernovae—and to follow their trajectories through the galaxy. The Compton team's conclusions have held up well.

Then, in the late thirties, Compton organized a number of conferences on cosmic rays, the last of which was held in Chicago during the summer of 1939. Many European scientists were in attendance, among them Werner Heisenberg, the brilliant discoverer of the "uncertainty principle." But war clouds were on the horizon, and within two years, Compton and he were on opposite sides of the race to build an atomic weapon. Cosmic rays had proved to be Compton's entry into atomic physics.

III

But how did Compton come into physics in the first place? The story is out of a Tom Swift or Hardy Boys novel.[6] One could imagine a sketch of the plot on the back dust jacket that would read something like this:

> Growing up in a small Ohio town at the turn of the 20th century, a boy becomes fascinated by astronomy and airplanes. Using savings from household chores, he buys a telescope from the Sears-Roebuck catalogue for $3.95. Builds his own camera and mounts it on nearby college telescope to photograph Halley's Comet. Makes and flies more than a thousand model airplanes, researching the properties of airfoils. At age 16, using hand tools, constructs and flies in his own 27-ft wingspan, wood and muslin glider with specially designed balancing system. Publishes first article in *Fly* magazine. Aided by older brother, begins experimental physics work on the recently discovered x-radiation while in college. Parents encourage service as missionary. But with their blessing, sees calling in life to serve others through scientific discovery, and follows brother to famous eastern graduate school where he continues x-ray studies. Teaches at a university. Tries industry. Works for Westinghouse Electric, where he invents sodium vapor lamp now used on highways everywhere. During WWI, works for air force, invents first turn and bank indicator. Yearns to get back to pure research on own projects. Following post-doctoral year at renowned Cavendish Laboratory, becomes chair of little-known midwestern university physics department at age twenty-eight. Ends up making world-shaking discoveries about x-rays. Awarded Nobel Prize for Physics in 1927 at thirty-five.

The story seems incredible, yet it all happened. I almost hate to elaborate on it for fear of diminishing its genuine drama, but I have to dwell a bit on the discovery for which Compton is chiefly known and for which he won the Nobel Prize, the so-called "Compton Effect."[7]

As one reads the history of science, things often look easy—one result after another, leading up to where we are today. What an illusion! In physics, during the early part of the twentieth century, the reality was a boiling ferment of discovery and extended controversy. And the young Compton was working in the middle of it. What his Compton Effect experiments demonstrated—precisely and for the first time—was Einstein's conjecture that light is not just a wave, it also comes in "quanta"-like particles. His work provoked a crisis in physics—how, after all, could anything really be both a wave and a particle? Soon the other side of the coin would be turned up as well: seemingly material particles, like electrons, are not just particles, they are waves too! And within a few years, Heisenberg and Schrödinger outlined the synthesis we now call "quantum mechanics," the most comprehensive, highly confirmed theory of matter and light we have today. No wonder Compton's work seemed like Nobel material.

To understand what was going on, we have to recall some history. Max Planck had come up with the quantum idea back in 1900. He was studying the radiation emitted by hot, incandescent substances. He saw that the frequencies of such radiation do not range continuously over the spectrum, but are discrete and particular to each substance. The only way to make sense of this, he figured, was to imagine that the excited atoms which produce the radiation must somehow be restricted to certain specific energy states—as he put it, they must be "quantized." As a result, he argued, the atoms could only emit or absorb energy in integral multiples of these same unit amounts. He called these bits of energy, "quanta." This seemed to be what the observations about radiation required.

So began the strange story of the quantum. The idea worked mathematically, but no one, not even Planck himself, believed it was more than a mathematical device, arranged to fit the data. Radiation was a wave phenomenon, and waves and discontinuous bits just do not go together. Somewhat later, however, in 1905, in one of the papers of that "miracle year" of his, Einstein showed that if you really go with Planck's idea, you can use it to explain a remarkable phenomenon about light, the "photo-electric effect." You can explain why light waves striking one side of a thin sheet of metal shoot off, not other waves, but electrons, discrete individual particles, from the other side. And shoot them off with an energy precisely correlated with the light frequency you use—just as Planck's hypothesis suggests might be the case. Maybe light waves could behave like little particles, knocking other particles around! Einstein had formulated a "quantum theory of light."

But no one believed in Einstein's light quanta—or "photons," as they came to be called—any more than they had believed in Planck's. So the years went by. By the early twenties, physicists had accepted Einstein's astonishing theory of relativity and even the amazing 1915 theory of gravity, but *no one* accepted his quantum theory of light! Even those, like Niels Bohr, who used Planck's original quantum idea in creating his own beautiful theory of the planetary atom, did not give any credence to Einstein's application of it to light. Everyone knew that light really was a wave. Light could be diffracted and polarized and, when two light beams hit each other, they interfered with each other, just like water waves do. Maybe light frequencies just came in "bunches" that were somehow like jolts or pulses, but *never* particles.

In the meantime, the close study of x-rays was advancing apace. No one was completely sure what x-rays were, but they clearly seemed to be waves—high frequency electromagnetic waves, produced in an x-ray tube by a stream of electrons striking a metal plate. Essentially, they were light at frequencies above the visual range. But what were their specific properties? All through the early 1900s, experimenters played with them, reflecting, diffracting, and polarizing them, filtering them, and sending them through and bouncing them off various substances to see what effects there were. In graduate school and, later, at the Cavendish, Compton was studying these effects. X-rays went right through human bodies, but when they hit metals or crystals, they were found to "scatter" in all directions, much as ocean waves send up spray when they hit a rocky shore. Some observers had found that this scattered or "secondary" radiation did strange things—it seemed to have a directionality to it and, most extraordinarily, to have a different, longer wavelength than the primary rays. What could be going on?

IV

When he arrived at Washington University in the fall of 1920, Compton immediately began a close examination of the question. He relished being on his own. He had gone there, he said, and not to a larger, more eminent institution, precisely so that he could think his own thoughts and pursue his own line of experiments without being unduly influenced by others. He designed his own equipment and blew his own glass for his x-ray tubes. He worked nights, in the basement of the science building, so that the vibrations from student and faculty feet would not disturb his measurements, and my mother often brought him meals. Over two years, in experiment after experiment, he accumulated the evidence he needed: yes, that odd x-ray behavior did take place; the direction of the secondary, scattered rays depended on the angle at which the incident rays impacted a surface; and their wavelengths did increase. He measured these effects precisely. The problem was that nothing in standard electro-magnetic theory "allowed" this to happen. Respectable waves can bounce around, penetrate things, be diffracted, and all the rest, but what makes them what they are, is their wavelength. That does not change.

As one historian put it, it is as if you held up a red rose to a mirror and its reflection turned violet.[8] This does not happen with visible light—when you look in the mirror you see a red rose. The wavelengths seem to stay the same. But with x-rays, with high frequency light in other words, it *was* happening. Compton tried for months to explain this in terms of wave theory, but finally gave up and turned to Einstein's idea of light quanta instead. Everything fell into place. You could treat the light quanta just as if they were like little billiard balls, and they could be envisioned colliding with billiard-ball-like electrons on the surface of the target. Just as with the balls on the pool table, what should happen does happen—the collision sends the quantum and the electron in precisely predictable directions, at precisely predictable angles with respect to one another, and with precisely predictable momenta and energies. In the process, you can predict that the light must give up some energy, and should relax somewhat as it bounces off. It should then have a precisely calculable, longer wavelength—just as his observations showed that it did. Theory and experiment were in perfect agreement.[9]

In December of 1922, Compton reported his discovery to the American Physical Society's annual meeting. It so happened that a German physicist, Arnold Sommerfeld, was visiting in the United States and heard the lecture. He wrote in great excitement to Niels Bohr, "The most interesting thing that I have experienced in America … is a work of Arthur Compton in St. Louis. After it, the wave theory of Roentgen-Rays will become invalid …"[10] He was right. The word spread through Europe. Sommerfeld named it the "Compton Effect" and put it in his 1923 textbook on quantum theory. It took a few years more, but the proposition that light is both wave and particle was here to stay.

However, during the interval, there was disagreement back in America. Classical electro-magnetism was not going down without a fight. In a lovely confrontation, the work by the little-known young man from the small midwestern university was strongly disputed by the well-known elder statesman from the elite university in the East. Harvard professor William Duane asserted that his measurements failed to accord with those of young Compton. They debated at the next meeting of the Physical Society and exchanged visits to each other's laboratories, but to no avail. At the summer 1924 meeting of the British Association for the Advancement of Science in Toronto, another debate was staged. Afterwards, a friend of Compton's, a distinguished Indian physicist named C. V. Raman, said to him, "Compton, you are a very good debater, but the truth isn't in you!"[11] In the end, though, it *was* in him: Duane himself found defects in his own experiments and went on to confirm and refine Compton's results. The two ended up close friends. This is not always the way science works, but the way it is supposed to.

Arthur Holly Compton did not aim to remake modern physics. He was a smart, ingenious, dirt-under-the-nails experimentalist who never let up. He was too modest when he once wrote to his father that he was just someone who was good at handwork and "a plain, everyday hard plugger." But he was close. Compton was the polar opposite of an Einstein or a Bohr—he let the experiments guide his thought, not the other way around. And those experiments helped to bring down classical physics and usher in a new era. His later adventures with cosmic rays and plutonium were more public; this adventure was a solitary one.

In later life, he went on to other things—to help his little-known midwestern university begin its journey to national leadership, and to write and lecture on education, religion, and public policy. He was indeed a citizen scientist. He helped win a war and, after it was over, he worked for world peace. NASA named one of its space telescopes the "Compton Gamma Ray Observatory." And there is now a Compton crater on the moon. Much of this will fade from memory. But the "Compton Effect" is destined to live on beyond him—as long as science is done, his "effect" will be there. Not bad for a small-town Ohio boy. ⊙

Notes

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3Dempster MacMurphy, "Piccard Flight May End Compton-Millikan Debate on Cosmic Ray Properties," *Chicago Daily News*, May 27, 1933.

4Arthur H. Compton, "Cosmic Rays as Electrical Particles," *Physical Review* 50 (December 15, 1936).

5"Cosmic Clearance," *Time: The Weekly Newsmagazine* 27 (January 16, 1936): 28–32.

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7Arthur H. Compton, "X-rays as a branch of optics" (Nobel lecture, December 12, 1927).

8Edmund Blair Bolles, *Einstein Defiant: Genius versus Genius in the Quantum Revolution* (Washington, DC: Joseph Henry Press, 2004), 106.

9Roger Stuewer, *The Compton Effect: Turning Point in Physics* (New York: Science History Publications, 1975).

10Bolles, *Einstein Defiant*, 102.

11Arthur H. Compton, *The Cosmos of Arthur Holly Compton* (New York: Alfred Knopf, 1967), 37.