One hundred years since Albert Einstein's annus mirabilis

Part 1

By Peter Symonds
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This is the first part of a four-part series on Einstein's scientific contributions. Parts two, three and four will be published on July 12, 13 and 14 respectively.

June 30 marked 100 years since Albert Einstein's scientific paper "On the Electrodynamics of Moving Bodies" was received by the prestigious German scientific journal *Annalen der Physik* for publication. Its unassuming title disguised a revolution in scientific thought. Better known as the special theory of relativity, the paper revised the fundamental conceptions of space and time that had been at the foundation of physics for more than 200 years. Further extended and elaborated in 1915 to the general theory of relativity, it remains one of the two central pillars of modern physics.

While relativity theory is the contribution for which he is best known, Einstein produced four other scientific papers in 1905. All of them showed the spark of genius and have been widely influential. Indeed, the consequences of his first paper in March, which broke with the orthodox view of light as a wave, were no less significant than his relativity theory. Einstein's postulate that light could behave as lumps of energy, or quanta, formed a key element of what, by the mid-1920s, developed into quantum mechanics—the second pillar of physics.

Remarkably, these ground-breaking papers, produced in the space of six months, came from an unknown 26-year-old physicist employed as a technical assistant by the Swiss patent office in Bern. Apart from his own close circle of young friends and colleagues, he was working in relative isolation without the guidance of, or close collaboration with, any of the leading physicists of the day. Looking back on this astonishing output, scientists and historians of science marvel at what is commonly referred to as Einstein's *annus mirabilis*—his miraculous year.

The scientific upheaval ushered in by Einstein has not only altered our comprehension of nature, from the internal workings of the atom to the character of the universe itself, but also opened the door to an array of technologies. No sphere of chemistry or physics has been left untouched by quantum mechanics, which is essential to our understanding of electronics and integral to the design of microchips that are behind the staggering developments in computers and communications. Quantum mechanics is also fundamental to molecular chemistry, and thus to our knowledge of DNA and genetics, and to the expanding field of biotechnology.

Special relativity predicted that mass could be converted to energy, and vice versa, and thus provided the key to understanding nuclear energy. In doing so, it unlocked the secret to what powered the Sun and other stars, as well as to their formation and development. General relativity has fundamentally changed our view of the universe. The theory predicted that the universe could be expanding, over a decade before this was corroborated by observational data, and laid the groundwork for our understanding that the cosmos evolved from an initial "Big Bang".

The foundations of modern physics were established by an entire generation of physicists, including Neils Bohr, Erwin Schrödinger, Werner Heisenberg, Max Born, Paul Dirac and Satyendranath Bose—to name just a few of the most prominent and brilliant. Many of them drew inspiration, directly and indirectly, from Einstein's work of 1905. A century later, physicists are still preoccupied with resolving the far-reaching theoretical consequences of the advances of that year.

While an individual of genius, Einstein cannot be understood apart from his times. A century of rapid industrial expansion throughout Europe and the world had profoundly altered the character of science. Capitalism drove technical innovation which, in turn, provoked new scientific questions and provided new apparatus for their resolution. Science became an established profession rather than the pursuit of gentlemen of independent means, as it was in the eighteenth century. According to one estimate, the total number of scientists in the world expanded from a mere 1,000 in 1800 to 100,000 in 1900.

The impact of science and technology was evident in many aspects of daily life—from the telegraph, electric lighting and radio to medical advances—generating popular interest in scientific achievements and optimism about mankind's ability to comprehend the universe. Such sentiments were propagated in the popular press, in schools and colleges, and had deep roots in the protracted struggle against religion and superstition in the seventeenth and eighteenth centuries—known broadly as the Enlightenment.

At the same time, capitalism was wracked by underlying contradictions that were to erupt in world war in 1914. Rapid economic expansion in Europe and the spread of overseas colonial empires brought the major powers into conflict. Militarism and jingoism were on the rise. Beneath the apparently stable exterior there were also revolutionary undercurrents—most sharply expressed in the 1905 revolution in Russia. These deeper tensions were reflected in the existence of a mass socialist movement, which championed science and technology as critical for the rational reorganisation of society.

In the same year as Einstein was writing his pioneering scientific papers, another 26-year-old of genius, Lev Davidovich Bronstein, better known by his pseudonym Leon Trotsky, was at the centre of the revolutionary convulsions in Russia as chairman of the Petrograd Soviet of Workers' Deputies. Drawing the political lessons of those experiences, Trotsky formulated his Theory of Permanent Revolution that was to provide the essential strategic conceptions for the Russian Revolution of October 1917. Einstein and Trotsky were born in the same year and, while in widely different fields, both were driven beyond previously accepted frameworks to devise startling theoretical solutions to new and apparently intractable problems. While the parallel could perhaps be dismissed as a striking coincidence, it was not entirely accidental and points to the extent of Europe's intellectual, cultural and political ferment. [1]

Einstein's early life

Einstein was, in every sense, a product of his times. Born in Ulm in Germany in 1879, he grew up in Munich where his father and uncle operated an electrical engineering factory. From his parents, who were non-practising Jews, he imbibed a love of literature, culture and music. He learned the violin, which he continued to play throughout his adult life and took wherever he travelled. He developed an interest in science and mathematics from an early age, spurred on by his uncle and his own avid reading.

At school, Einstein developed a marked aversion to rote learning and discipline. His strong-willed independence found its first expression in an early period of religiosity—in opposition to his irreligious parents. This abruptly ended, as he later explained, at the age of 12. "Through the reading of popular scientific books, I soon reached the conviction that much in the stories of the Bible could not be true. The consequence was a positively fanatic [orgy of] freethinking coupled with the impression that youth is intentionally being deceived by the state through lies; it was a crushing impression. Suspicion against every kind of authority grew out of this experience, a sceptical attitude towards the convictions which were alive in any specific social environment—an attitude which has never again left me." [2]

When his family moved to Italy in 1894, Einstein went to Switzerland at the age of 16 to seek entry to the prestigious Swiss Federal Polytechnic School (ETH), where he was finally admitted in 1896. He skipped lectures that did not interest him, followed his own predilections and initially spent a lot of time in the experimental laboratory. His determined independence rubbed many of his lecturers up the wrong way. An exasperated Professor Heinrich Friedrich Weber reportedly declared: "You are a smart boy, Einstein, a very smart boy. But you have one great fault: you do not let yourself be told anything." [3]

Einstein had a close group of friends who passionately discussed the latest developments in physics as well as philosophy and culture. These included classmate Marcel Grossmann, to whom Einstein later turned for mathematical assistance in the formulation of General Relativity, and engineer Michele Angelo Besso, who remained a close friend throughout his life. Einstein also met and fell in love with fellow student Mileva Maric, a Serbian, who came to relatively liberal Switzerland to further her education. She was only the fifth woman to be admitted to the ETH to study physics.

Einstein completed his ETH diploma in 1900. His reputation for stubborn independence was undoubtedly one of the reasons why he failed to obtain a position at the ETH or as a university assistant elsewhere. With the assistance of Grossman, he obtained a post at the Bern patent office in 1902, and the following year he and Mileva were married. His work at the patent office not only allowed him time to pursue his own scientific research, but also stimulated a lifelong fascination with ingenious devices and experiments. Here, he honed his extraordinary ability to penetrate to the essentials of a scientific problem.

Physicist and colleague John Wheeler wrote: "Every morning he faced his quota of patent applications. Those were the days when a patent application had to be accompanied by a working model. Over and above the applications and the models was a boss, a kind man, a strict man and a wise man. He gave strict instructions: explain very briefly, if possible in a sentence, why the device will work or why it won't; why the application should be granted or why it should be denied. Day after day Einstein had to distill the central lesson out of objects of the greatest variety that man has power to invent. Who knows a more marvellous way to acquire a sense of what physics is and how it works?"[4]

At the Bern patent office, Einstein published his first scientific papers, worked towards a doctorate, and, in 1905, as he later described it, "a storm broke loose in my mind." [5] To appreciate what was tormenting Einstein, it is necessary to examine the development of nineteenth century physics.

The achievements of nineteenth century physics

In contrast to other branches of science, such as biology or geology, that focus on the complexities of life or the earth's structures, physics deals with the more essential underlying objective laws of nature as a whole: how and why do objects move; what are light and sound; and what is the basic structure of matter? Its roots lie in the sixteenth and seventeenth centuries in the broad intellectual and political struggle of the emerging bourgeoisie against feudalism and the domination of the Roman Catholic church. Without a battle against religious dogma, no science was possible.

As Friedrich Engels succinctly explained: "At that time natural science also developed in the midst of the general revolution and was itself thoroughly revolutionary; it had indeed to win in struggle its right of existence. Side by side with the great Italians from whom modern philosophy dates, it provided its martyrs for the stake and dungeons of the Inquisition... The revolutionary act by which natural science declared its independence... was the publication of the immortal work by which Copernicus, though timidly and, so to speak, only from his death-bed, threw down the gauntlet to ecclesiastical authority in the affairs of nature." [6]

By declaring that planetary movements could be more simply explained by orbits around the Sun, rather than the Earth, Nicolaus Copernicus provoked an investigation into the nature of motion itself. Galileo Galilei set out to rebut the obvious objections. If the Earth is moving around Sun, why is there no evidence of its motion? Why are objects thrown into the air not left behind? In fact, what was moving the Earth in the first place?

The answers challenged the assumption, going back to Aristotle, that movement required a force. Galileo's law of inertia, later refined by Isaac Newton, declared that objects, including the Earth, do not require an external force to move, but, rather, will continue to move at constant speed unless slowed by friction or air resistance. So the Earth, and everything on it, would continue to move around the Sun because there was no opposing force.

Newton's *Philosphiae Naturalis Principia Mathematica*, published in 1697, brought together and extended the work of Copernicus and Galileo, as well as the astronomers Tycho Brahe and Johannes Kepler. He identified three fundamental laws of motion and, to apply them, developed, along with Gottfried Wilhelm Leibniz, an entire branch of mathematics—differential and integral calculus.

Unlike Galileo, Newton insisted that the law of inertia applied only to motion in a straight line, not circular motion. What constrained the planets to move in the elliptical orbits around the Sun, described by Kepler? Newton concluded that the same gravitational force of attraction that impelled objects to fall to Earth operated between any masses, including the Sun and the planets. Based on his universal law of gravitation and laws of motion, he was able to explain the paths of the planets.

Newton's achievements were indispensable intellectual weapons in the efforts of the materialist philosophers of the Enlightenment to demonstrate that nature obeyed comprehensible, objective laws, rather than incomprehensible divine will. In Newton's scheme, God was no longer needed to maintain the motion of the planets which could be calculated to a high degree of accuracy with the tools of calculus. Newton's caveat that God had to set the planetary system in motion was later abolished by an understanding, beginning with Immanuel Kant, of the origins and evolution of the solar system.

To be continued

Notes:

1. More fully examined in "Toward a reconsideration of Trotsky's legacy

and his place in the history of the 20th century", David North, *World Socialist Web Site,* 29 June, 2001
2. "Autobiographical Notes" in *World Treasury of Physics, Astronomy and Mathematics*, editor Timothy Ferris, Little Brown & Company, 1991, p. 578
3. *Subtle is the Lord: The Science and the Life of Albert Einstein*, Abraham Pais, Oxford University Press, 1982, p. 44
4. "Albert Einstein" by John Archibald Wheeler in *World Treasury of Physics, Astronomy and Mathematic,* op. cit, p.568
5. Quoted in *Einstein 1905 The Standard of Greatness,* John S. Rigden, Harvard University Press, 2005, p.2
6. *Dialectics of Nature*, Friedrich Engels, Progress Publishers, 1976, p.22