Modern Times

Revised Edition

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Chapter One: A Relativistic World

The modern world began on 29 May 1919 when photographs of a solar eclipse, taken on the island of Principe off West Africa and at Sobral in Brazil, confirmed the truth of a new theory of the universe. It had been apparent for half a century that the Newtonian cosmology, based upon the straight lines of Euclidean geometry and Galileo's notions of absolute time, was in need of serious modification. It had stood for more than two hundred years. It was the framework within which the European Enlightenment, the Industrial Revolution, and the vast expansion of human knowledge, freedom and prosperity which characterized the nineteenth century, had taken place. But increasingly powerful telescopes were revealing anomalies. In particular, the motions of the planet Mercury deviated by forty-three seconds of arc a century from its predictable behaviour under Newtonian laws of physics. Why?

In 1905, a twenty-six-year-old German Jew, Albert Einstein, then working in the Swiss patent office in Berne, had published a paper, "On the electrodynamics of moving bodies", which became known as the Special Theory of Relativity. Einstein's observations on the way in which, in certain circumstances, lengths appeared to contract and clocks to slow down, are analogous to the effects of perspective in painting. In fact the discovery that space and time are relative rather than absolute terms of measurement is comparable, in its effect on our perception of the world, to the first use of perspective in art, which occurred in Greece in the two decades c.500-480 BC.

The originality of Einstein, amounting to a form of genius, and the curious elegance of his lines of argument, which colleagues compared to a kind of art, aroused growing, world-wide interest. In 1907 he published a demonstration that all mass has energy, encapsulated in the equation E = mc2, which a later age saw as the starting point in the race for the A-bomb. Not even the onset of the European war prevented scientists from following his quest for an all-embracing General Theory of Relativity which would cover gravitational fields and provide a comprehensive revision of Newtonian physics. In 1915 news reached London that he had done it. The following spring, as the British were preparing their vast and catastrophic offensive on the Somme, the key paper was smuggled through the Netherlands and reached Cambridge, where it was received by Arthur Eddington, Professor of Astronomy and Secretary of the Royal Astronomical Society.

Eddington publicized Einstein's achievement in a 1918 paper for the Physical Society called "Gravitation and the Principle of Relativity". But it was of the essence of Einstein's methodology that he insisted his equations must be verified by empirical observation and he himself devised three specific tests for this purpose. The key one was that a ray of light just grazing the surface of the sun must be bent by 1.745 seconds of arc -- twice the amount of gravitational deflection provided for by classical Newtonian theory. The experiment involved photographing a solar eclipse. The next was due on 29 May 1919. Before the end of the war, the Astronomer Royal, Sir Frank Dyson, had secured from a harassed government the promise of £1,000 to finance an expedition to take observations from Principe and Sobral.

Early in March 1919, the evening before the expedition sailed, the astronomers talked late into the night in Dyson's study at the Royal Observatory, Greenwich, designed by Wren in 1675-6, while Newton was still working on his general theory of gravitation. E.T. Cottingham, Eddington's assistant, who was to accompany him, asked the awful question: what would happen if measurement of the eclipse photographs showed not Newton's, nor Einstein's, but twice Einstein's deflection? Dyson said, "Then Eddington will go mad and you will have to come home alone." Eddington's notebook records that on the morning of 29 May there was a tremendous thunderstorm in Principe. The clouds cleared just in time for the eclipse at 1.30 pm. Eddington had only eight minutes in which to operate. "I did not see the eclipse, being too busy changing plates...We took sixteen photographs." Thereafter, for six nights he developed the plates at the rate of two a night. On the evening of 3 June, having spent the whole day measuring the developed prints, he turned to his colleague, "Cottingham, you won't have to go home alone." Einstein had been right.

The expedition satisfied two of Einstein's tests, which were reconfirmed by W.W. Campbell during the September 1922 eclipse. It was a measure of Einstein's scientific rigour that he refused to accept that his own theory was valid until the third test (the "red shift") was met. "If it were proved that this effect does not exist in nature", he wrote to Eddington on 15 December 1919, "then the whole theory would have to be abandoned". In fact the "red shift" was confirmed by the Mount Wilson observatory in 1923, and thereafter empirical proof of relativity theory accumulated steadily, one of the most striking instances being the gravitational lensing system of quasars, identified in 1979-80. At the time, Einstein's professional heroism did not go unappreciated. To the young philosopher Karl Popper and his friends at Vienna University, "it was a great experience for us, and one which had a lasting influence on my intellectual development". "What impressed me most", Popper wrote later, "was Einstein's own clear statement that he would regard his theory as untenable if it should fail in certain tests.... Here was an attitude utterly different from the dogmatism of Marx, Freud, Adler and even more so that of their followers. Einstein was looking for crucial experiments whose agreement with his predictions would by no means establish his theory; while a disagreement, as he was the first to stress, would show his theory to be untenable. This, I felt, was the true scientific attitude..."