Arthur Stanley Eddington

Born: 28 Dec 1882 in Kendal, Westmorland, England
Died: 22 Nov 1944 in Cambridge, Cambridgeshire, England

Arthur Eddington's father, Arthur Henry Eddington, taught at a Quaker training college in Lancashire before moving to Kendal to become headmaster of Stramongate School. He died of typhoid in an epidemic which swept the country in 1884 before his son was two years old. Arthur Eddington's mother, Sarah Ann Stout, came from Darlington and, like her husband, was also from a Quaker family. On Arthur Henry Eddington's death she was left to bring up Arthur and his older sister with relatively little income. The family moved to Weston-super-Mare where at first Arthur was educated at home before spending three years at a preparatory school.

In 1893 Arthur entered Brymelyn School in Weston-super-Mare which was mainly for boarders but he did not board at the school, being one of a small number of day pupils. The school provided a good education within the limited resources available to it and allowed Arthur to excel in mathematics and English literature. His progress through the school was rapid and he earned high distinction in mathematics. The level to which the school was able to take Arthur was, however, not very advanced and his good grounding in mathematics stopped short of reaching the differential and integral calculus.

In 1898 he was awarded a scholarship of £60 a year for three years by Somerset County (Weston-super-Mare is now in Avon but it was at that time in Somerset). Eddington had not reached sixteen years of age at the time, and so officially he was too young to enter university. It was a problem which was solved quickly, however, and did not cause him to delay his entry to Owens College, Manchester which he attended from 1898 to 1902. In his first year of study Eddington took general subjects before spending the next three years studying mainly physics. Although on a physics course, Eddington attended the mathematics lectures, being greatly influenced by one of his mathematics teachers, Horace Lamb. Of course the financial position of his family meant that they were not able to provide him with financial support but his outstanding academic work allowed him to win a number of highly competitive scholarships to provide enough money to let him complete his B.Sc. course with First Class Honours in 1902.

He was awarded a Natural Science scholarship of £75 a year to study at Trinity College, Cambridge, near the end of 1901. Entering Trinity in 1902 he received, in March 1903, a Mathematics Scholarship of £100 a year instead of the Natural Science scholarship. At Trinity he was taught by E T Whittaker, A N Whitehead and E W Barnes. He became Senior Wrangler in the Mathematical Tripos in 1904 and graduated with a M.A. in the following year. After graduating, he began a research project in the Cavendish Laboratory on thermionic emission but it appears not to have gone too well and he gave up the project. He began research in mathematics, also in 1905, but this was no more successful than his work in physics although he was to make use of the ideas many years later when he applied these early research ideas in mathematics to an astronomy problem.

Before the end of 1905 Eddington had made the move to astronomy with his appointment to a post at the Royal Observatory at Greenwich. Astronomy had been a topic of interest to him from an early age and he had been given a loan of a 3 inch telescope when less than 10 years old which had heightened his interest. On being appointed to fill a vacancy at the Royal Observatory he was immediately involved with a research project which had been underway since 1900 when photographic plates of Eros had been taken over the period of a year. Eddington's first task was to complete the reduction of these photographic observations to determine an accurate value for the solar parallax. Plummer writes in [17]:-

He had introduced his method of analysis of two star-drifts, and his prevailing interest in statistical stellar astronomy was concentrated on the systematic motions and distribution of the stars throughout his Greenwich years.

Eddington was a Smith's prize winner for an essay on the proper motions of stars in 1907, and he was awarded a Trinity College Fellowship. George Darwin, a son of Charles Darwin and Plumian professor of astronomy at Cambridge, died in December 1912. In 1913 Eddington was appointed to fill the vacant position of Plumian Professor of Astronomy. There were in fact two chairs of astronomy at Cambridge, the other being the Lowndean chair. Originally the Plumian chair covered the experimental side of the subject while the Lowndean chair covered the theoretical side. Although this distinction had become somewhat blurred over the years the appointment of Eddington was certainly seen as an appointment in experimental astronomy. However, the holder of the Lowndean chair died towards the end of 1913 and, in 1914, Eddington became director of the Cambridge Observatory. In doing so he effectively took over responsibility for both theoretical and experimental astronomy at Cambridge. Shortly after his appointment as director of the Cambridge Observatory he was elected a Fellow of the Royal Society.

Shortly after taking up his role of leading astronomy research at Cambridge, World War I broke out. As we noted above Eddington came from a Quaker tradition and, as a conscientious objector, he avoided active war service and was able to continue his research at Cambridge during the war years of 1914-18. This was, however, not an easy time for him giving him a highly stressful period right at the beginning of his tenure of the Cambridge chair.

Eddington made important contributions to the theory of general relativity. His interest in this topic started in 1915 when he received papers by Einstein and by de Sitter which came to him via the Royal Astronomical Society. He became interested in this theory, particularly since it provided an explanation for the previously noticed, but unexplained, advance of the perihelion of Mercury. He lectured on relativity at the British Association meeting in 1916 and produced a major report on the topic for the Physical Society in 1918.

In the following year Eddington led an eclipse expedition to Principe Island in West Africa. Its aim was to verify the bending of light passing close to the sun which was predicted by relativity theory. At that time such observations of stars close to the sun in the sky could only be made during a total eclipse. He sailed from England in March 1919 and by mid-May had his instruments set up on Principe Island. The eclipse was due to occur at two o'clock in the afternoon of 29 May but that morning there was a storm with heavy rain. Eddington wrote (see for example [6]):-

The rain stopped about noon and about 1.30 ... *we began to get a glimpse of the sun. We had to carry out our photographs in faith. I did not see the eclipse, being too busy changing plates, except for one glance to make sure that it had begun and another half-way through to see how much cloud there was. We took sixteen photographs. They are all good of the sun, showing a very remarkable prominence; but the cloud has interfered with the star images. The last few photographs show a few images which I hope will give us what we need ...*

He remained on Principe Island to develop the photographs and to try to measure the deviation in the stellar positions. The cloud made the plates of poor quality and hard to measure. On 3 June he recorded in his notebook:-

... one plate I measured gave a result agreeing with Einstein.

The results from the Africa expedition provided the first confirmation of Einstein's theory that gravity will bend the path of light when it passes near a massive star. Eddington wrote, in a parody of the *Rubaiyat* of Omar Khayyam (see for example [6]):-

Oh leave the Wise our measures to collate
One thing at least is certain, light has weight

One thing is certain and the rest debate
Light rays, when near the Sun, do not go straight.

Eddington lectured on relativity at Cambridge, giving a beautiful mathematical treatment of the topic. He used these lectures as a basis for his book *Mathematical Theory of Relativity* which was published in 1923. Einstein said that this work was:-

... the finest presentation of the subject in any language.

In addition to his work in relativity theory Eddington also did important work on the internal structure of stars. He discovered the mass-luminosity relationship for stars, he calculated the abundance of hydrogen, and he produced a theory to explain the pulsation of Cepheid variable stars. His early research on this is contained in the important work *The Internal Constitution of Stars* (1926). Eddington had a long running argument with James Jeans over the mechanism by which energy was created in stars. He wrote, correctly of course, that as to the process of generating energy:-

... probably the simplest hypothesis ... is that there may be a slow process of annihilation of matter.

Jeans, however, favoured the theory that the energy was the result of contraction. Of course this is not entirely wrong since a star when it forms will initially heat up under the energy generated by contraction before nuclear reactions begin and then provide the energy source for most of the star's life.

Among Eddington's many books were philosophical works such as *The Nature of the Physical World* (1928), *New Pathways of Science* (1935) and *The Philosophy of Physical Science* (1939). Eddington's rather unusual view of the importance of the history of a subject comes over in these works. He believed that familiarity with the history of a subject was a hindrance to creative research in that subject. The authors of this archive would have to register their strong disagreement with Eddington on this issue!

Eddington had a fascination with the fundamental constants of nature and produced some surprising numerical coincidences most of which were published after his death in *Fundamental Theory* (1946), a book prepared for publication by Whittaker. He writes in that book that his aim was to determine the relation between the sizes of different physical systems. Ronan writes [18]:-

Eddington, hard-headed mathematician and down-to-earth astronomer though he might be, possessed a mystical side to his nature and the last years of his life were spent in an attempt to construct a huge relativistic synthesis of the physical universe, an edifice in which the bricks would be subatomic and astronomical evidence of the observer and the mortar the underlying mathematical relationships between them.

In [9] Kilmister delves deeply into the ideas which led Eddington to the theories he put forward in *Fundamental Theory* in attempting to unite quantum mechanics and general relativity. Kilmister explains how Eddington considered that epistemology is at the basis of physics, that physical laws and physical constants are the consequences of the condition of observation. It was Dirac's 1928 paper on the wave equation of the electron which had first set Eddington on the path of seeking ways to unify quantum mechanics and general relativity. Kilmister explains how Dirac's use of spinors had surprised Eddington and led him to study a generalisation of the Dirac algebra. His work on algebras which would give a symmetrical description of nature is also examined in [19].

Eddington was knighted in 1930 and received the Order of Merit in 1938. He received many other honours including gold medals from the Astronomical Society of the Pacific (1923), the Royal Astronomical Society (1924), The National Academy of Washington (1924), the French Astronomical Society (1928), and the Royal Society (1928). In addition to election to the Royal Society, he was elected to the Royal Society of Edinburgh, the Royal Irish Academy, the National Academy of Sciences, the Russian Academy of Sciences, the Prussian

Academy of Sciences and many others. He was invited to give the Bakerian Lecture of the Royal Society of London in 1926 when he lectured on *Diffuse matter in interstellar space.*

Plummer writes in [17]:-

To his splendid equipment as a mathematical physicist he owed much ... A bold imagination was coupled with an exceptional knowledge of those features which are accessible to observation. ... To launch out into unknown seas, to be venturesome even at the risk of error, Eddington felt himself called, and the reward of the pioneer came to him. ... Simplicity and modesty were his outstanding characteristics ...

Eddington's achievements are summed up in [3] as follows:-

He was a gifted astronomer whose original theories and powers of mathematical analysis took his science a long way forward; he was a brilliant expositor of physics and astronomy, able to communicate the most difficult conceptions in the simplest and most fascinating language; and he was an able interpreter to philosophers of the significance of the latest scientific discoveries.

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