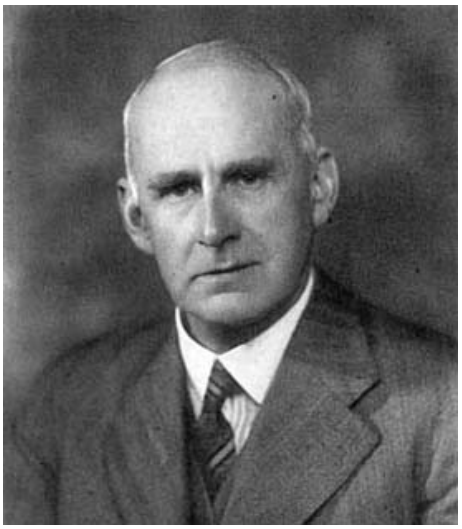
Arthur Stanley Eddington



British astronomer, physicist, and mathematician **Arthur Stanley Eddington** (December 28, 1882 – November 22, 1944) founded the science of astrophysics, in which he pioneered the study of stellar evolution, subatomic sources of stellar energy, and diffuse matter in interstellar space. He was the first scientist to propose that the tremendous heat production at a star's core is what keeps a star from collapsing under its own gravity and forwarded a theory that every star ends its life by collapsing to a small, dense, glowing object known as a white dwarf. Indian-born American astronomer Subrahmanyan Chandrasekhar amended this theory when he determined that Eddington's calculations did not hold for stars with a mass greater than about 1.44 times that of the Sun. Chandrasekhar showed that a more massive star would be crunched by its own gravity and become either a neutron star or a black hole. Eddington's ideas led him to the conclusion that unifying quantum theory and general relativity theory would allow for the calculation of certain universal constants. He asked: "What do we really observe? Relativity theory has returned the answer – we only observe relations. Quantum theory returns another answer – we only observe probabilities."

Eddington was born at Kendal in Westmorland to Quaker parents. His father died during a typhoid epidemic before his son was two years old. Arthur's mother was left with little financial means to bring up her son and his older sister. The family relocated to Weston-super-Mare, where Eddington was taught at home before spending three years at a preparatory school. In 1893 he became a day student at the Brymelyn School in Weston where he excelled in mathematics and English literature. Five years later he was awarded a scholarship that allowed him to enter Owens College, Manchester, where he

mainly studied physics but was greatly influenced by his mathematics teacher, Horace Lamb. Eddington won several highly competitive scholarships that provided him with enough money to continue his university education, and, in 1902, he earned his B.Sc. with First Class Honors. A National Science scholarship allowed him to proceed to Trinity College, Cambridge, where he became Senior Wrangler in the Mathematical Tripos in 1904 and was granted his M.A. the following year. The next year he was appointed chief assistant at the Royal Observatory at Greenwich and then was elected a Fellow of Trinity. At the age of thirty Eddington was appointed Plumian Professor of Astronomy, and, in 1914, he added the title of Director of the Observatory. He remained in both positions until his death of cancer in 1944.

In his first book, *Stellar Movements and the Structure of the Universe* (1914), Eddington summarized his mathematically elegant investigations. At a time when it was still mostly assumed that there was only one galaxy in the universe, he forwarded the thesis that the spiral nebulae, cloudy structures seen in the telescope, were galaxies like the Milky Way. After receiving papers by Einstein and Dutch cosmologist Willem de Sitter, Eddington lectured on relativity at the British Association meeting (1916). In 1918, he delivered his "Report on the Relativity Theory of Gravitation" written for the Physical Society. The next year, Eddington organized an expedition to Principe Island in West Africa to photograph the stars in the neighborhood of the Sun during a total solar eclipse. The purpose of this experiment was to determine whether stars adjacent to the Sun's rim appeared to have shifted away from the Sun and their normal position relative to each other.

Although difficult to measure, Eddington's observations were the first confirmation of Einstein's general relativity prediction that light rays are bent when subjected to the strong gravitational field of a massive star. With his popular writings, including *Space, Time and Gravitation* (1920) and his treatise *Mathematical Theory of Relativity* (1923), Eddington captured the intellectual imagination of the

generation. Eddington's own contribution to the field of relativity was his brilliant modification of non-Euclidean geometry, which led to a geometry of the cosmos. After Belgian astronomer Georges Lemaître published his thesis of an expanding universe, Eddington made his own investigations, which he explained to the general reader in *The Expanding Universe* (1933).

Eddington demonstrated that in order to remain in equilibrium the inward gravitational pressure of a star must balance the outward radiation and gas pressure. This led him to conclude that there was an upper limit on the mass of a star, about 50 solar masses. Otherwise the balance between gravitation and radiation pressure could not be maintained. The reason that some stars pulsate is that they are verging on instability. Eddington's discovery showed that the more massive a star the greater is its luminosity. This relationship in turn allows the calculation of the mass of a star from its intrinsic brightness. His early research in this area is contained in *The Internal Constitution of Stars* (1926) and in *Stars and Atoms* (1928). From 1930 on, Eddington gave so many popular lectures on relativity that British physicist Sir Joseph John Thomson jested that Eddington had convinced thousands of people that they actually understood it. Eddington, who was concerned with the relation of physics to philosophy, wrote a number of philosophical books, including *The Nature of the Physical World* (1928) and *The Philosophy of Physical Science* (1939). His last book, *Fundamental Theory* (1946), published posthumously by his biographer Sir Edmund Whittaker, had as its goal finding the relation between the sizes of different physical systems, and to unite quantum mechanics and general relativity.

Motivated by his deeply held Quaker beliefs, during World War I Eddington declared himself a pacifist. His religious faith also found expression in his popular treatises. He insisted that the world's meaning could not be discovered from science, but must be sought through apprehension of spiritual reality. Eddington began a 1938 Tarner lecture with the remarkable statement: "I believe there are 15,747,724,136, 275,002,577,605,653,961,181,555,468,044,717, 914,527,116, 709,366,231,425,

076,185,631,031,296 protons in the universe and the same number of electrons." This quantity, which can be expressed as $136 \cdot 2^{256}$, is now known as the "Eddington number." The number was never taken very seriously and has since been discredited, but it sprang from his deep insights that were revolutionary at the time.

Eddington held that dimensionless constants of the cosmos hold the key to the world. In addition, he maintained that the structure and even numerical values of physical theories can spring from the abstract algebra of group theory. Although Eddington had a healthy suspicion of the rigor of mathematics, he became one of the earliest scientists to champion the importance the theory of groups would play in physics. In his both *New Pathways to Science* (1935), he explained that to give an account of the external world, a super-mathematics was needed in which the operations are unknown as are the quantities they operate on. Eddington claimed that such a super-mathematics existed, namely, the Theory of Groups. He wrote:

> "The Theory of Groups is usually associated with the strictest logical treatment. I doubt whether anyone hitherto has committed the sacrilege of wrenching it away from a setting of pure mathematical rigor. But it is now becoming urgently necessary that it should be tempered to the understanding of a physicist, for the general conceptions are beginning to play a big part in the progress of quantum theory. Various mathematical tools have been tried for digging down to the basis of physics, and at present this tool seems the most powerful to use."

Eddington proceeded to describe the theory of groups in a way that physicists would understand and appreciate by means as he put it, "So with rough argument and make-shift illustration I am going to profane the temple of rigor."

Eddington's name has been given to a five-year space mission planned for 2008 that is to look inside stars, determine their precise chemical composition, and in some cases, the size of their energy-generating hearts.

Quotation of the Day: "Proof is the idol before whom the pure mathematician tortures himself." – Sir Arthur Stanley Eddington