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The Eclipse to Confirm the General Theory of Relativity

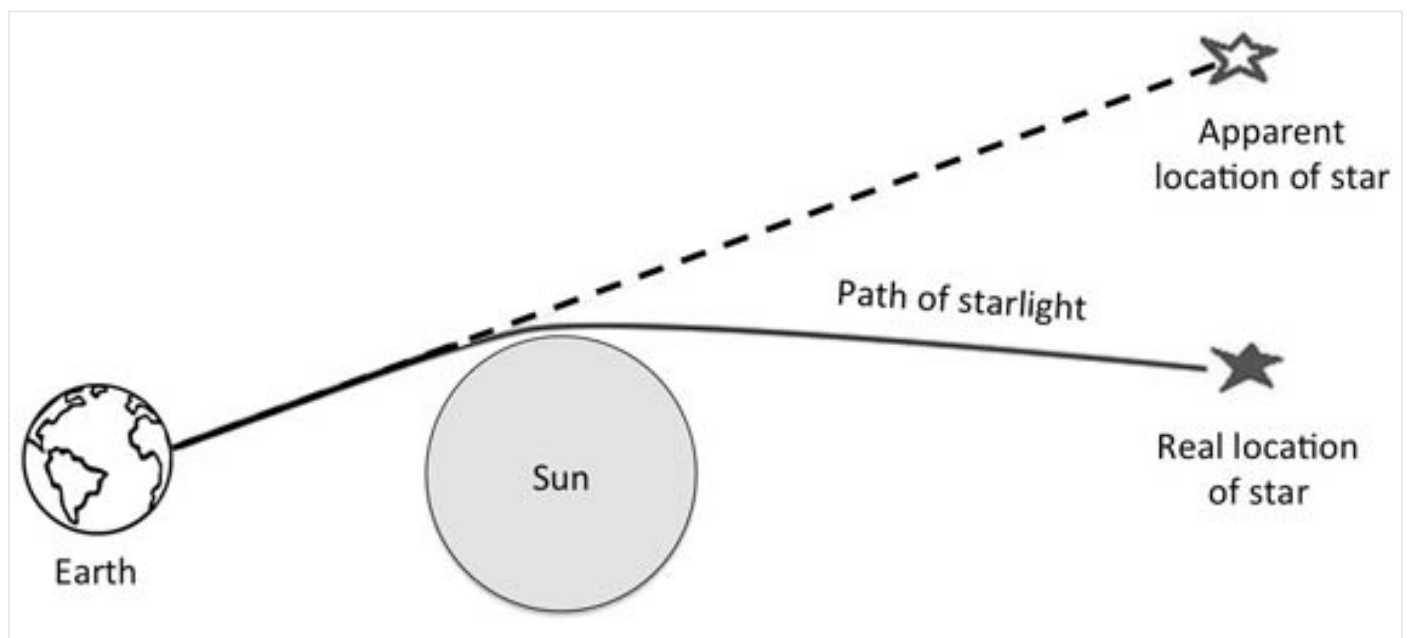
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One of **the milestones of the science of light** commemorated during this **International Year of Light and Light-based Technologies** is “the embedding of light in cosmology through general relativity in 1915,” that is, the celebration of **the centenary of Albert Einstein’s general theory of relativity**.

As Adolfo de Azcárraga, president of the **Spanish Royal Society of Physics** (RSEF), points out in his book titled *Albert Einstein, His Science and His Time*, Einstein’s theory contained **a spectacular prediction: “light also possessed ‘weight’,** i.e., it should be attracted and deflected by celestial bodies.” Since the equivalence between acceleration and gravity extends to electromagnetic phenomena and light is an electromagnetic wave, **light rays should bend in the presence of a gravitational field.** Einstein had already realized that **the only way to experimentally verify this theoretical prediction was for a total solar eclipse** to take place since this would make it possible to photograph a star near the Sun when observed from Earth without the presence of strong sunlight. Well, **on May 29, 1919** there would be a solar eclipse, which would be total on some parts of the Earth’s surface and **would make it possible to verify that light rays are bent by gravity.**

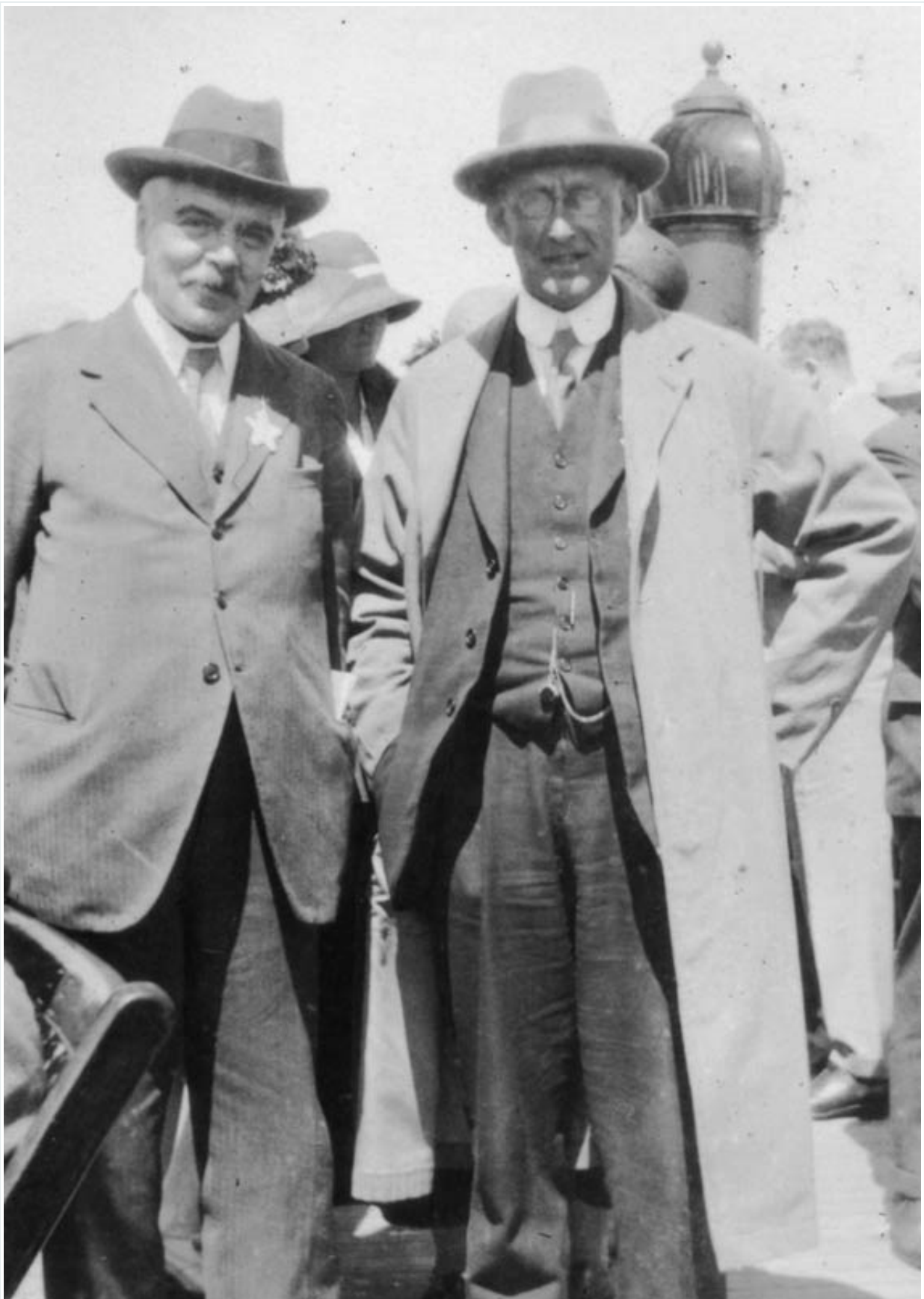


Frank Dyson (1868-1939), Astronomer Royal and director of **the Royal Greenwich Observatory**, was the first to realise that the eclipse of May 29, 1919 was a unique opportunity to verify Einstein’s theory. The British astronomer **Arthur Eddington** (1882-1944), renowned scientist, devout Quaker, convinced pacifist, Director of **the Cambridge University Observatory** and one of the few scientists who at that time

understood Einstein's general theory of relativity, published in *The Observatory*, in March 1919, the article "[The total eclipse of 1919 May 29 and the influence of gravitation on light](#)". In this paper he pointed out that the solar eclipse of May 29, 1919 would be «a very favourable opportunity of investigating the influence of the Sun's attraction on the course of a ray of light» and thus verify the prediction of the general theory of relativity, published by Einstein in November 1915. According to this theory, light rays flush with the solar corona should suffer a deviation of 1.74 arc seconds. Eddington also said that «if successful photographs are obtained at the eclipse, these will be compared with photographs already taken for the purpose with the astrographic telescopes at Greenwich and Oxford, which show the same stars in their undistorted relative positions.» Eddington also noted that «if gravitation acts on light, the momentum of a ray will gradually change direction when acted on by a transverse field of force, just as that of a material projectile does.» According to Newtonian dynamics «the total deviation of a light ray on passing the Sun, if it grazed the surface, would be 0.87 arc seconds, or half the Einstein deflection.»

In order to check the deviation of light rays due to the presence of a gravitational field, **two British scientific expeditions were organized**. Both expeditions emulated the expeditions during the eighteenth century made by Malaspina, Cook or La Perouse, the Challenger expedition or Darwin's voyage aboard the Beagle in the nineteenth century, as well as the British Antarctic expedition of the early twentieth century, known as Discovery, where leading figures in the Heroic Age of Antarctic Exploration, including Robert Falcon Scott who led the expedition, and Ernest Shackleton participated.

Frank Dyson was responsible for organizing two parallel expeditions, each of which would **go to a point near the Earth's equator**. The eclipse was not visible in Europe and although it could be seen as a partial eclipse from most of South America and Africa, it was only a total solar eclipse if seen from locations on a narrow strip beginning at the Pacific Ocean, and crossing Brazil, the Atlantic and Equatorial Africa to the Indian Ocean. The expedition led by **Charles Davidson** headed to **Sobral**, on the northeast coast of Brazil, and the other led by **Arthur Eddington** went to the **island of Príncipe**, at that time Portuguese colonial territory, in what is now a small country called **São Tomé and Príncipe in the Gulf of Guinea**. Eddington's base was in the cocoa plantation at Roça Sundy. The two expeditions left the UK in March and arrived at their destinations in good time to make all necessary preparations for a correct observation of the total eclipse. **The eclipse lasted 6 minutes and 51 seconds**, one of the longest in the twentieth century. During the eclipse, many photographs of stars around the Sun's corona (which normally would not be visible because of the strong sunlight) were taken and for whose further study, several months were needed. **Eddington was responsible for the analysis of the data collected on the island of Príncipe**, while Dyson was responsible for the data from Sobral.



Frank Dyson (left) and Arthur Eddington (right). Credit: AIP Emilio Segrè Visual Archives, W. F. Meggers Collection.

According to the theory of general relativity, light rays passing near the sun should deviate slightly because light is bent due to the gravitational field of the sun. This effect can be observed experimentally only during eclipses, because at other times the brightness of the Sun obscures the light emitted by these stars. **The actual and apparent positions of about thirteen stars were compared** and the conclusion was unequivocal: analysis of the measurements of the light ray deviations confirmed that the

gravitational field of the Sun exerts an influence on light, as predicted by Einstein's theory. **One of the most spectacular theoretical predictions ever made had been verified just four years after it had been put forward.** The physicist, mathematician and science writer **Joseph P. McEvoy**, in his book *Eclipse* (The Science and History of Nature's Most Spectacular Phenomenon) published in 1999 states that «a new theory of the universe, the brainchild of a German Jew working in Berlin, was confirmed by an English Quaker on a small African island.» **Eddington** considered his verification of the deflection of light, which he glimpsed via an early analysis of his plates while still on Príncipe, **the greatest moment of his life.**

On October 30, 1919 Eddington, Dyson and Davidson submitted an article with the results of the data collected on Sobral and Príncipe titled *"A determination of the Deflection of Light by the Sun's gravitational field, from Observations Made at the solar eclipse of May 29, 1919"*. This was **published in January 1920** and provided **conclusive evidence that validated Albert Einstein's general theory of relativity.** On November 7, 1919 the London newspaper *The Times* announced with fanfare: **"Revolution in Science/New Theory of the Universe/Newtonian Ideas Overthrown."** Three days later, on November 10, 1919, the *New York Times* headlines read: **"Light All Askew in the Heavens/Men of Science More or Less Agog Over Results of Eclipse Observations/Einstein Theory Triumphs."** However, not only the British and American newspapers echoed the success of the expedition and its findings. Almost in the antipodes of the UK, on January 20, 1920 the Australian newspaper *Western Argus*, on page 2, published **"Revolution in Science/New Theory of the Universe."**

Both the expedition to Sobral and that to the island of Príncipe, together with the results obtained from the measurements taken during the total solar eclipse of May 29, 1919, crossed not only geographical borders but also the cultural borders between scientists and the general public, and catapulted Einstein to worldwide fame. A *star* had been born thanks to the measurement of the deflection of light from other stars.

More information

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