EINSTEIN, EDDINGTON, AND THE ECLIPSE:
TRAVEL IMPRESSIONS

ESSAY

INTRODUCTION

The total solar eclipse that occurred on 29 May 1919—perhaps considered the most famous solar eclipse ever—was exceptional for a variety of scientific, political, social, and even religious reasons. At just over five minutes of totality (more precisely, 302 seconds), it was a long eclipse. Behind the sun appeared the Taurus constellation, which included the Hyades, the brightest star cluster in the ecliptic. The preparations of the British teams that observed it, and which are the subject of this essay, took place in the middle of the Great War, during a period of international instability. The observation locations selected by these specialists were in the tropics, in distant regions unknown to most astronomers, and thus required extensive preparations. These places included the city of Sobral, in the north-eastern state of Ceará in Brazil, and the equatorial island of Príncipe, then part of the Portuguese empire, and today part of the Republic of São Tomé and Príncipe. Located in the Gulf of Guinea on the West African coast, Príncipe was then known as one of the world's largest cocoa producers, and was under international suspicion for practicing slave labour. Additionally, among the teams of expeditionary astronomers from various countries—including the United Kingdom, the United States, and Brazil—there was not just one, but two British teams. This was an uncommon choice given the material, as well as the scientific and financial effort involved, accentuated by the unfavourable context of the war. The expedition that observed at Príncipe included Arthur Stanley Eddington (1882–1944), the astrophysicist and young director of the Cambridge Observatory, as well as the clockmaker and calculator Edwin Turner Cottingham (1869–1940); the expedition that visited Brazil included Andrew Claude de la Cherois Crommelin (1865–1939), and Charles Rundle Davidson (1875–1970), both experienced astronomers at the Greenwich Observatory (see pp. 67, 68 and 74).

The astronomical objectives of the British expeditions were unusual, and therefore unknown to most astronomers. Normally, astronomers observed eclipses for four main goals. The observation of a total solar eclipse had long been performed in the context of positional astronomy, specifically with the purpose of rigorously determining the second and third contacts that define the range of totality in which the moon completely hides the sun. However, since the second half of the nineteenth century, astrophysical observations had become common practice, concentrating instead on the solar surface in order to clarify its physical and chemical composition. Another approach was to focus on observations of unusual magnetic and electric effects. These last two were precisely the goals of the Brazilian and American teams respectively, but not those of the British teams. Between the last quarter of the nineteenth century and the first decade of the twentieth century, astronomers took advantage of eclipses to try to spot the hypothetical planet Vulcan, supposedly situated between the sun and Mercury, and proposed as a way of accounting for the anomaly of the orbit of Mercury, which was finally explained by Einstein's theory of general relativity (GRT).

Organized by Eddington, the British expeditions were intended to verify—to either confirm or invalidate—one of the astronomical predictions of the recently-proposed GRT, which was grounded in revolutionary fundamental considerations. Proposed by the Swiss-German physicist Albert Einstein (1879–1955), known then only to a narrow circle of scientists, the theory predicted the bending of light rays as they passed close to large gravitational masses. To accomplish their task, British astronomers had to take background photographs of bright stars during the eclipse, when the light rays they emitted bent as they passed close to the surface of the sun. These photographs were to be compared with those taken of the same set of stars a few months later, when the sun was no longer interposed between the stars and the observer, and therefore no longer deflecting the rays they emitted. By comparing the two sets of photographs, it was possible to measure the deviation between the actual positions of the stars and their apparent positions recorded during the eclipse, and hence to determine if there was deviation and, in the case that there was, to check if its value coincided or not with that predicted by Einstein (see p. 69).

The organization of the British expeditions owes much to the persistent vision of Astronomer Royal Sir Frank Watson Dyson (1868–1939) (see p. 72) who, aided by Eddington, convinced scientific and governmental authorities of its scientific worth in deciding between Isaac Newton's theory of gravitation and the GRT, Einstein's new theory of gravitation. Although both theories predicted that light from a star passing close to the sun would bend slightly, the prediction of Einstein's final theory (announced in 1915, and published in 1916), was double the prediction of Newton's classical theory, if one accepted the corpuscular nature of light. Dyson sponsored this initiative despite the risk that Newton, the exponent of British science, would be overthrown by a physicist from a country with which the United Kingdom was engaged in a war that was proving to be remarkably lethal on account of the innovative use of mustard gas produced by German science.

As was traditional in the field of astronomy, the expeditionary teams set up networks of contacts so that they could receive all the necessary support they needed for the realization of their scientific activities from the astronomers of their host countries. In the case of the 1919 eclipse, their work was all the more adventurous, as it involved travel to far-away places foreign to them. The 1919 eclipse became a focus of attention among experts and lay people alike, especially in the places where the eclipse was observed in its totality, and it subsequently became the subject of mounting noteworthiness, which extended to the public sphere.

The results of the observations at Sobral and Príncipe constituted the first major steps towards confirming the light-bending hypothesis. They were also responsible for Einstein's meteoric rise in the popular imaginary, which began shortly after the public announcement of the results on 6 November 1919 at the joint meeting of the Royal Society of London and the Royal Astronomical Society, held at Burlington House in the heart of London. They also marked the beginning of the gradual process of the acceptance of the GRT, the scientific content of which few understood. Those who did understand it had the Herculean task of decoding its concepts and results in a language accessible to the lay public.

Eddington was a key player in this process. He was among the first to understand and adopt the special theory of relativity (SRT) and the GRT, and to embrace their popularization in a clear and enthusiastic manner. He likewise promoted the compelling idea that the results of the two British expeditions, organized during the troubled days of the Great War, not only proved the Swiss-German physicist's theories, but also constituted an unmistakable example of scientific internationalism. While science is often viewed within the scientific and popular imagination as holding no geographical or political borders, and as a neutral and universal activity constructed exclusively on the merits of participants, the expeditions discussed in this essay illustrate the real, and sometimes dangerous, liaisons between science, politics, and religion.

In what follows, I discuss the scientific, political, social, and religious aspects undergirding the preparation and materialization of these adventurous expeditions. I begin by discussing what led to the unlikely encounter between physicist Einstein and astrophysicist Eddington, mediated by another accidental astronomical encounter, and I discuss the unexpected religious motivations behind the expeditions. I then analyse the collective effort to prepare the two expeditions, as well as the involvement of local communities. I conclude with an assessment of the astronomers' travels, their ensuing observations, and the initial effects of the public announcement of their findings.

AN UNLIKELY ENCOUNTER

While Eddington is not known to the lay public, Einstein has long been one of the world's most famous scientists, often selected for the cover of magazines like *Time*, and as person of the century. Yet, in 1919, Albert was not yet Einstein. That is to say, in the year of the eclipse, Einstein did not yet enjoy the reputation he acquired precisely after the announcement of the favourable results of the observations of the British expeditions on 6 November, at the joint meeting of the two prestigious British scientific societies. This was followed two months later by the release of an article authored by Dyson, Eddington, and Davidson, titled "A determination of the deflection of light by the sun's gravitational field, from observations made at the total solar eclipse of May 29, 1919."[1] Thus, one cannot take into account the celebrity Einstein enjoys today. Instead, we are left to wonder about young Eddington's interest in the theory of relativity. What prompted him to organize not just one, but two expeditions to the tropics at a time when observing solar eclipses was primarily geared towards astrophysical purposes, and when the British scientific community, including the great Cambridge dons, reacted negatively to the theory of relativity? As is typical in the study of history, the explanation involves a confluence of various factors: in this case, those of both an astronomical and religious nature, peppered by several coincidences.

After finishing mathematics and physics at the Zurich Polytechnic Institute in 1900, Einstein applied for a position at the Swiss Federal Patent Office in Bern where he began working in 1901, when he became a Swiss citizen.[2] His stint at the patent office was crucial to the considerations he made in the "miraculous year" of 1905, in his articles that introduced the SRT, with its reconceptualization of space, simultaneity and time, and matter. The year of the eclipse brought profound changes in Einstein's life, both scientific and personal. At the private level, he finally got a divorce from Mileva Maric, his former classmate, with whom he had been married since 1903, later marrying his cousin Elsa Einstein.[3] At the scientific level, he reached the apex of over ten years of work.

His attempts to generalize the SRT began in 1907 and ended eight years later in late 1915. Since 1912 Einstein had been a professor of physics at the University of Berlin, a member of the Prussian Academy of Science, and the director of the future Kaiser Wilhelm Institute of Physics, having been forced to reassume his German citizenship and thus become a Swiss-German citizen. With the outbreak of World War I, and in response to the German Manifesto supporting the war signed by 93 reputed German scientists, including Max Planck (1858–1947), Wilhelm Roentgen (1845–1923), Fritz Haber (1868–1934), and Walther Nernst (1864–1941), Einstein publicly expressed his pacifism, writing the "Manifesto to the Europeans."

In 1911, Einstein realized that any theory that accommodated gravitation also anticipated an astonishing astronomical effect—the deflection of light passing close to large gravitational masses. He did so before reaching the theory's final formulation, realized in 1915–16, at which time he added to the prediction of light bending, two other astronomical predictions, including the explanation of the anomalous orbit of Mercury, known since the mid-nineteenth century.

Urban Le Verrier's (1811–1877) resounding success in predicting the existence of Neptune, the first trans-Uranian planet to be identified through the disturbances it caused to the trajectory of Uranus, led him to conjecture the existence of Vulcan, a hypothetical small planet believed to be situated between the sun and Mercury, as an explanatory solution to Mercury's precession. However, if the confirmation of Neptune's existence was a resounding success of the Newtonian theory of gravitation, the quest to discover Vulcan proved a huge failure.

Among the astronomers who chased Vulcan during expeditions to observe total solar eclipses, was the American astronomer Charles Dillon Perrine (1867–1951), who since 1909 was the director of the Observatory of Cordoba, Argentina. It was through astronomer Erwin Finlay Freundlich (1885–1964), Einstein's friend and one of the few experts aware of GRT astronomical predictions in the early 1910s, that Perrine heard that this new physical theory explained Mercury's precession. He immediately gave it enormous credit and set out to lead the first expedition to test light bending.[4]

During the total solar eclipse of 10 October 1912, which was observed in Brazil, Perrine led an Argentinian team to Cristina, Brazil, near Passa Quatro, where in opposition to Perrine's team, Brazilian and British teams were stationed to fulfil traditional astronomical purposes. However, the cloudy and rainy weather thwarted the astronomers' expectations, preventing any observations. But this setback was counterbalanced by a stroke of luck. In Rio de Janeiro, Perrine met Eddington, who mentioned the encounter in a letter to his mother, written from Passa Quatro, on 26 September:

> The Argentine & Chilean expeditions were going to Christina [sic.] about 50 miles further on. The former (Perrine & his 3 assistants) came to dinner with us at our hotel in Rio on Thursday evening and we had a very jolly time. I hope to have time to visit their camp at Christina [sic.] before the eclipse.[5]

It may well have been through this chance encounter that Eddington first had contact with the light bending prediction.[6]

Eddington had begun his career at the Royal Greenwich Observatory, working under the supervision of Astronomer Royal Dyson. By 1912, he was Plumian Professor of Astronomy and Experimental Philosophy at Cambridge University, having succeeded George Darwin, and in 1914, he became director of the Cambridge Observatory, as well as a Fellow of the Royal Society of London. He allied observational astronomical acumen with a great mastery of physics and mathematics, a rare combination for most astronomers. It is unclear what Eddington's involvement was with the SRT, which was known in Cambridge scientific circles fond of ether theory, and therefore not sensitive to relativity. What we do know is that in early 1915, even before Einstein completed the GRT, Eddington published an article revealing his familiarity with the SRT, in which he referred to the deflection of light predicted in the context of attempts at the generalization of SRT.[7]

Occurring right in the middle of the Great War, the year 1916 proved to be a turning point in Eddington's career, not only for his innovative conceptions of star structure, but also for his encounter with Einstein's theory of gravitation, mediated by Dutch astronomer Willem de Sitter (1872–1934). De Sitter was one of a limited number of Dutch scientists who followed Einstein's work and knew about the latest developments of the GRT. Unable to attend the meeting of the British Association for the Advancement of Science to be held that year in Newcastle, a "restricted area" because of the war, de Sitter sent Eddington his three-part article on the subject. This article was the basis for Eddington's presentation at the meeting.[8]

Afterwards, Eddington read Einstein's original article on the GRT, also provided to him by de Sitter. Eddington quickly recognized the elegance, logical foundations, and potential of the new theory, and he determined to disseminate it not only in the United Kingdom, but also in the United States. In 1918, he published a book on GRT titled *Report on the Relativity Theory of Gravitation*, the first treatise on the subject in English, followed by another less technical volume in 1920, aimed at a more general public, titled *Space, Time and Gravitation. An Outline of the General Relativity Theory*, which went through various editions. Shortly afterwards, Eddington's publication, *The Mathematical Theory of Relativity* (1923), was considered by Einstein the best essay on the theme in any language.[9]

WARTIME PREPARATIONS

What is clear is that Eddington first encountered and became interested in the GRT during the Great War. However, moving from knowledge to action was a giant step, especially given that the preparation and organization of two expeditions (rather than just one) took place in particularly adverse times. The role of the Astronomer Royal was essential to their success.

Though Dyson was not as enthusiastic as Eddington about the virtues of the GRT, he quickly recognized the importance of the 1919 eclipse for testing light bending. He immediately anticipated its relevance to astronomy and British astronomers.[10] As early as 9 March 1917, at a meeting of the Royal Astronomical Society, in a presentation titled "On the opportunities afforded by the eclipse of 1919, May 29 of verifying Einstein's theory of gravitation," he drew attention to the eclipse, pointing out that it was an excellent opportunity for astronomers to use the recent physical theory (GRT) which explained the advance of Mercury's perihelion, an effect that had long baffled them.[11] He also referred to the difficulty—and in some cases, the impossibility—of using photographs of past eclipses that depicted background stars to understand this phenomenon. While he confessed that Davidson's attempts to use the photographs taken with the Greenwich Observatory's astrographic telescope during the 1905 eclipse observed in Sfax, Tunisia had failed, he still maintained the suitability of this telescope for the 1919 observations.

As previously mentioned, to test the deflection of light, it was necessary to photograph stars within a visual proximity to the sun during totality. The more stars, and the brighter, the better. As Dyson emphasized, the eclipse of 29 May 1919 offered exceptional conditions from this point of view, since the sun's background on this occasion would include the Taurus constellation, and the star cluster known as the Hyades, which was rich in bright stars. It was necessary to compare by juxtaposition the photographs of these stars taken during the eclipse with other photographs that showed the same stars in the same position in the sky, but without the interposition of the sun between them and the observer. Next, the necessary reduction of data took place, in order to calculate if there was deflection, and if so, its value and the error involved. The minute effect predicted by Newton's and Einstein's gravitational theories were respectively 0.87" and 1.75" seconds of arc, demonstrating the extreme skill and accuracy required of these observations and measurements.

Dyson further pointed out that before the May 1919 eclipse there would be another total solar eclipse on 8 June 1918 in the United States, but dismissed the involvement of a British team given the unfavourable war context as well as the adverse astronomical conditions for verifying deflection. He relegated those observations to American astronomers.

After the failures of 1912 and 1914, the astronomer Heber Doust Curtis (1872–1942) from Lick Observatory in California was indeed the first to photograph the stars in the background during the 1918 eclipse. However, the eclipse was very short and with few stars in the sun's vicinity. Furthering his inaccuracy, he did not have adequate equipment, as William Wallace Campbell (1862–1938), director of the observatory, had brought it on a past expedition to observe the 1914 eclipse in Crimea. With the onset of war hostilities, the German team, headed by Freundlich, who had also travelled to Crimea to test light's deflection, was taken prisoner. The American team only had their instruments confiscated, as they belonged to a country not (yet) involved in the war. However, by 1918, the equipment was still in transit back to its home observatory.

Back in 1911, Freundlich had contacted the Lick Observatory with the expectation that it might hold photographic plates from past eclipses showing deflection. This was why Campbell and Curtis were among the first astronomers to be interested in the GRT prediction. Following the 1918 eclipse observations, the analysis of plates and data reduction was delayed for over a year, as Curtis was summoned to war in the meantime. By the time Campbell was finally able to communicate their results at the Royal Astronomical Society in London in July 1919, the reduction of data from the 1919 eclipse observations had already begun, with better prospects than those discussed by Campbell, which proved inconclusive.[12]

At the meeting of 9 March 1917, geographer and astronomer Arthur Robert Hinks (1873–1945), secretary of the Royal Geographical Society, presented an analysis of the possible sites for observing totality during the 1919 eclipse. He listed seven different locations, describing the partial information already collected, both in terms of weather and accessibility.[13] From Brazil, he mentioned:

> There is a town called Sobral, with a population of 35,000, at the foot of lofty hills, and a smaller town Santa Anna, which is almost on the central line. Sobral is connected with the port of Camocim by railway, so that if a station in Brazil is to be occupied I think it would be best.

From Príncipe he reported that it had recently become known for politicians' criticism of "slave cocoa," that its terrain was rough, that it seemed to offer good observational conditions, and that there were rails for transporting materials to the cocoa plantations, though he also confessed his ignorance of its weather conditions.[14]

In fact, on 23 February 1917, Hinks, at Dyson's request, contacted the Lisbon Geographical Society (Sociedade de Geografia de Lisboa, SGL), requesting information on Príncipe's climate, sanitation and accessibility, and also asking for a detailed map of the island. The correspondence took place between March and April 1917. Through the contacts that Ernesto de Vasconcelos (1852–1930), Secretary General of the SGL, established with the Colonial Agriculture Society (Sociedade de Agricultura Colonial), Hinks received not only a map of the island, but also several maps of meteorological data for the years 1914, 1915, and 1916, and one for the month of May 1917.[15] Although the Lisbon Astronomical Observatory (Observatório Astronómico de Lisboa, OAL) was not contacted at this time, its deputy director, Colonel Frederico Thomaz Oom (1869–1930) published on 3 January in the journal *O Instituto* of the University of Coimbra, an article pointing to the favourable conditions of Príncipe, and urging astronomers to study its weather conditions.[16]

It was also around this time that Henrique Carlos Morize (1860–1930), a prestigious Brazilian astronomer, the director of the Observatory of Rio de Janeiro since 1908, and founder and first president of the recent Brazilian Academy of Sciences (Academia Brasileira de Ciências), took the initiative to send British astronomers detailed information about the conditions in Sobral.[17] He was deeply engaged in the popularization of science, in the formation of a Brazilian scientific community, and in asserting Brazil's role and recognition in the international context. From his perspective, the 1919 eclipse afforded an opportunity not to be missed.

On 10 November 1917, at a meeting of the Joint Permanent Eclipse Committee, formed as a result of the concerted efforts of the Royal Society of London and the Royal Astronomical Society, the decision was taken to organize two expeditions, if the many uncertainties of war were overcome. The Government Grant Committee was also asked to provide a total funding budget of £1100, including £1000 for travel and £100 for the adaptation of existing instruments.[18] A subcommittee consisting of astronomers Dyson, Eddington, Alfred Fowler (1868–1940), and Herbert Hall Turner (1861–1930) was in charge of preparing the two expeditions. Thus, Dyson supported the verification of the GRT, to the point of enthusiastically promoting two expeditions in order to double their probability of success.

He was well aware of the fiascos of the two previous expeditions, including the 1912 trip to Cristina, and the 1914 voyage to Crimea; given these previous debacles, the 1918 eclipse did not look promising.

The subcommittee met in May, June, and November 1918. It began by deciding that Eddington and Cottingham would travel to Príncipe, and use the objective lens of the astrographic telescope of Oxford Observatory. Meanwhile, astronomer Davidson and Jesuit priest and astronomer Aloysius Laurence Cortie (1859–1925), both experienced in such expeditions, would travel to Sobral and use the lens of the astrographic telescope of Greenwich Observatory that had already proved adequate in the observation of the 1905 eclipse. Cottingham would be in charge of the clock mechanisms necessary for the constant alignment of the celostats (reflecting mirrors) with the sun, due to the movement of the earth.

The subcommittee's dreams almost collapsed when it was concluded that it would be difficult to meet the conditions for transporting the material across the Atlantic by ship. However, following the announcement of the end of the war, at the meeting of 8 November 1918 their hopes were renewed, and they decided to take all the material to Greenwich, where preparations would be finalized so that the expeditions could depart at the end of February 1919. They then decided which extra material to use. In addition to the Oxford and Greenwich astrographic objective lenses equipped with sixteen-inch celostats, Cortie suggested using a four-inch telescope (with a nineteen-inch focus), which he himself had used in Sweden in 1914, complemented by an eight-inch celostat, which belonged to the Royal Irish Society.[19] A last-minute religious impediment led to the replacement of Cortie by Crommelin, who like Davidson was an astronomer at Greenwich Observatory.

On 11 November 1918 the armistice was signed. That same day, Eddington began an exchange of correspondence with the director of OAL, vice admiral César Augusto Campos Rodrigues (1836–1919), who charged Oom, the deputy director, to pursue it[20] (see p. 82). It focused primarily on logistics.[21] In this first letter, Eddington referred to Hinks' prior contact with SGL and requested additional information about Príncipe. The letter concluded by stating that Dyson recalled with affection the welcome he and the British team received when they travelled to Portugal to observe the total solar eclipse of 28 May 1900. The OAL astronomers excelled in providing logistical, material and scientific support, and at the same time skilfully seized the opportunity to claim greater scientific and social relevance for astronomy in Portugal.[22]

The letter's opening paragraph is particularly enlightening. Addressing OAL's Director, Eddington writes:

> Dear Sir,
> The Royal Society and the Royal Astronomical Society propose to send an expedition to the island of Príncipe to observe the total eclipse of May 29. The party will consist of Mr. Cottingham and myself, and we shall devote ourselves to measuring the deflection of light (if any) by the sun's gravitational field with a view to testing Einstein's theory of gravitation. You doubtless know that the 1919 eclipse is exceptionally favourable for this purpose.[23]

Eddington assumed that OAL's astronomers were aware of Einstein's new theory. It is quite possible that by reading *The Observatory*, which OAL received on a regular basis, Oom knew Dyson's article of 9 March 1917, which referred both to Einstein's theory and Príncipe's privileged location for the verification of light bending. This is all the more likely as Oom was also aware of the island's potential for observing the eclipse.[24]

Through the Lisbon observatory, Eddington and Cottingham were able to secure Portuguese support in establishing the most appropriate route for their trip, in getting steamboat passages (after having decided on stops and vessels to be taken), in the proper transport of instruments, and in customs tax exemptions. They also requested as detailed information as possible on weather conditions, suitable locations for observations and accommodation, and finally, on material and human support in the preparation of observations, including the possible presence of interpreters, as the travellers only spoke cursory French. The National Shipping Company (Companhia Nacional de Navegação) and the competent colonial institutions and individuals contacted by OAL—the Colonial Centre (Centro Colonial), the Colonial Agriculture Society, as well as the important private plantation owner Jerónimo José Carneiro made themselves immediately available to the astronomers.[25] By affirming the value of Portuguese astronomy and astronomical institutions to the great European power of Britain, Campos Rodrigues and Oom indirectly, but effectively, reinforced the nineteenth-century ties between science, power, and colonial empires.[26]

In addition to the various obstacles caused by the war on transatlantic transportation, the expeditioners feared that the December 1917 coup d'état, which took place in Portugal and brought Sidónio Pais to power would jeopardize their stop in Lisbon and their visit to OAL.[27] Fortunately, this did not happen.

Meanwhile, in the United Kingdom, with deserted observatories and little technical staff available, including mechanics, carpenters, and cabinetmakers, work began at the Greenwich Observatory under Davidson's wise direction. A skeleton of the tent armatures was constructed to be covered with tarpaulins to house the telescopes, steel tubes were purchased for the astrographic objectives, and the four-inch telescope tube was adapted from Cortie's tube telescope. Decisions were taken as to the photographic plates and the plate holders to be used, and the sixteen-inch celostats were tested and the eight-inch celostat was silvered and adapted to near-equatorial latitudes. Finally, everything was packed up for the voyage.

It is remarkable that the instruments used to detect the possible effect of light bending, which corresponded to a slight deviation of 1/60mm in the stellar positions on the plates, were not built from scratch, but were adapted and assembled with existing pieces from different observatories. The observations that confirmed light bending were not, therefore, detected by cutting-edge technology, highlighting the importance of technologies-of-use in science.[28]

EXPEDITIONERS AND OBSERVATION LOCATIONS

Of the four expeditioners, only two—Eddington and Crommelin—held PhDs in astronomy. Davidson was an astronomer recognized for his instrumental expertise and long track record of eclipse observations, and Cottingham was an accomplished clockmaker, a craft that he practiced with recognized precision and innovative skills: he was ranked among the best of the *métier*. Given the characteristics of the observations and measurements to be taken to verify the deflection of light, all team members were highly qualified professionals.

It was not easy to gather expeditionary personnel at the time, because most British scientists had been summoned to war service. Three of the expeditioners were between the ages of forty and fifty, and so when the war began, Eddington, who was in his early thirties, was in serious danger of being conscripted to military service if the war were to continue.

Eddington was a man of faith. As a member of the Society of Friends, a pacifist Protestant denomination also known as the Quakers, he was a conscientious objector on religious grounds.[29] For this position, he could have been easily misunderstood by his fellow British citizens and accused of anti-patriotism. His views could also have had negative implications on the scientific community if he was called upon and refused to perform military service. Astronomer Royal Dyson, who knew Eddington well and admired his work, wanted to avoid this potential conflict at all costs. Thus, with the onset of the war, Dyson negotiated an exemption from military service for Eddington on the grounds that he ran the Cambridge Observatory, one of Britain's most distinguished observatories, and that his work was "of national importance."[30] But as the war progressed and recruitment continued, with the age of enrolment being raised, the likelihood of revocation of this exemption increased as well. In this context, Dyson managed to negotiate the expedition's leadership as an alternative to military service. This is how, once again in the history of science, astronomy and religion joined hands, not because religious arguments supported scientific theses, but because religious options guided the planning and pursuit of scientific activities.

In the end, Eddington and Cottingham went to Príncipe, and Davidson and Crommelin headed for Sobral. While the final decision about who went where is usually taken for granted and never discussed or analysed, these decisions were not taken by chance, as everything was planned in minute detail. Since there is no certainty about why these choices were made, several plausible justifications can be advanced. At first glance, this was a multiple-choice problem as all the travellers were experienced experts and even had practice working together, as when Davidson and Eddington failed at Passa Quatro back in 1912. As the leader, it was natural for Eddington to choose for himself the location that offered the most difficult conditions. In Sobral, the British team would not be alone, having the company of two other expeditions, one Brazilian and one American. However, in Príncipe, there were no other expeditions, nor any other astronomers accompanying them. It is likely that Eddington chose Príncipe in the same spirit of extreme dedication and increased risk as Quaker missions to Europe to help suffering populations, regardless of their nationality.[31]

Additionally, secondary religious reasons may have reinforced or at least facilitated this choice. Davidson and Crommelin were both "practicing Catholics," and this was mentioned with satisfaction by local Brazilian newspapers as a factor they shared with the local population.[32] Perhaps it was also for this reason, that the astronomer initially assigned to Sobral was Father Cortie, an experienced Jesuit astronomer.

In the case of Eddington, who was accompanied by Cottingham, his religious background might have drawn him to a place that was also familiar to other notable Quakers: specifically, the Cadbury family, who were Príncipe's largest international cocoa buyers. If this connection played a role, it is difficult not to suspect that he was aware of the pressure exerted by Cadbury on local producers a few years earlier to ensure decent working conditions on their plantations. Understandably, these issues are not referenced in the correspondence between Eddington and the OAL, although all correspondents were likely aware of the conflicts that opposed the British and Portuguese empires over the issue of slavery in the Portuguese possessions in Africa.[33] They probably also shared a naive belief in the separation between the scientific and political spheres, a construction as useful for eclipsing dangerous liaisons in the past as in the present. Eddington's relaxed comments in his letters to his mother are only surprising at first glance for his omission of references to the labour problem, though he did make brief references to the use of local workers in baggage transport and in the installation of the observational facility. His descriptions highlight instead lush landscapes, island tours, social gatherings and recreational activities, *soirées*, and other events.[34] The same was true of the joint publication with Dyson and Davidson, in which details of the expeditions and of their results were presented, but which, once again, only briefly referred to the use of native labour, an issue I return to below.[35]

THE VOYAGES

Travel has always been central to the construction and consolidation of science. Among scientific voyages, expeditions have a prominent place: they connect science and power, economics and politics; they displace people, instruments and objects in movements dominated by unexpected adventures and setbacks; and in spite of the surgical precision put into their preparation, they are always subject to uncertainties that test the tenacity of the most stubborn expeditioners.

The two British expeditions involved nearly two years of wartime preparations, culminating in five minutes of observation, which were subject to unpredictable weather. Despite financial support from the British government, no equipment was acquired, and the accuracy of their measurements depended on instruments adapted from pre-existing parts held in various British observatories and collected at the Royal Greenwich Observatory for the final preparations. Expeditions moved more than two tons of material to tropical regions near the equator, at distances of just over 7200 km for Sobral and 5800 km for Príncipe. In the end, their success depended on the participation of astronomers from the countries where the observations were made, that is, Portugal and Brazil, as well as on members of the local elite of each country, and on workers and servants, who will forever remain anonymous.

In addition to scientific talks and publications, two of the British astronomers wrote more or less detailed accounts of their travels. Authored by experienced expeditioners, they offer a glimpse into the landscapes, places, peoples and experiences unrelated to their authors' daily routine. They are revealing both for what they refer to and for what they omit, recording their authors' personal perspectives on the selected events they narrate.

FROM LONDON TO FUNCHAL WITH A STOP IN LISBON

The trips were adventurous from the very start. The four travellers met at Euston train station in London on 7 March 1919.[36] Having in mind their unusual and bulky luggage, they arrived well in advance of their departure, but they could not avoid paying an extra fee for "glass," an incorrect classification for astrographic lenses made by company employees. After this first setback, they drove to Liverpool where more surprises awaited them. It was not easy to find where to deposit their luggage to be delivered the next day to the steamship, the Anselm. It was also difficult to find a hotel, as many were sold out, but eventually they managed to find one.

The next day, on 8 March, they headed to the harbour. Once aboard the Anselm, they waited a few hours for their luggage to be delivered to the ship. They were finally ready to leave for Lisbon. According to the exchange of correspondence with the OAL, due to the political situation in Portugal, there was a period when the expeditioners sought to sail directly to Madeira without stopping in Lisbon.[37]

Their impressions of the steamship were very positive. Larger and more comfortable than expected, with about 60 first-class passengers on board, the travellers shared well-placed cabins located at sea level: one was occupied by Eddington and Cottingham, and the other by Davidson and Crommelin. Despite the generally amenable conditions, the passage through the Bay of Biscay was turbulent, causing Crommelin and Cottingham temporary sea sickness.[38]

Although the war was officially over, life on board reflected wartime constraints—passengers could not be informed of their location or of the ship's route. Otherwise, everything seemed back to normal, especially with regard to the diversity, quality, and quantity of food, in which sugar, meat, white bread, and puddings abounded. The sociability was typical of transatlantic ship routes, including meals with the captain, and games and conversations among passengers of various nationalities, including a British amateur astronomer who was going on a mission to the Amazon.

Their arrival in Lisbon took place on the 12th, at a time that was difficult to precisely determine: Eddington noticed that the time followed on the boat differed from both Greenwich Mean Time and the official summer time followed in Portugal.[39] Oom, OAL's deputy director, with whom they had exchanged correspondence, was waiting for them at the pier. They visited the observatory for about two hours, met director Campos Rodrigues, "a charming old man, who looked as little like a Vice-Admiral as one could imagine," and they signed the OAL's guestbook and admired the estate where the observatory was located, full of blooming almond trees.[40] The trip to the observatory and their return to the boat were made in a car that Oom rented for three hours with the purpose of showing them a bit of Lisbon and, in particular, the Belém area.[41] Contrary to his impressions from 1912, in which Eddington commented that Lisbon did not look like a European capital at all, but instead, rather like a big trading post or a huge market, Eddington now noticed only that Lisbon seemed very peaceful, though it was full of soldiers, but had no police in sight.[42]

Added to all the uncertainties and setbacks of a trip planned in the middle of the Great War, was the previously-mentioned Portugal's instable political situation, which had begun at the end of 1917. In May 1918, Sidónio Pais garnered the presidency, along with the office of prime minister. This was accompanied by modifications he imposed on the republican matrix that had hitherto prevailed, giving his mandate a presidential and dictatorial stamp, and culminating in his assassination on 14 December 1918. In a letter to Oom, dated 8 February 1918, Eddington wrote: "We find that all boats to Lisbon have been cancelled for the present—I suppose owing to the revolution. I trust that you and the Observatory are unharmed." He was likely referring to the 1917 establishment of the Revolutionary Movement by Sidónio Pais. After all, it was completely possible to stop in Lisbon. No wonder, therefore, that they were surprised at the city's calmness when they arrived.

Apart from Eddington's reference to the revolution in his correspondence, Oom never made any comments on the national political situation. His *ethos* as a man of science guided his behaviour and reactions, which included providing scientific aid to expeditionary astronomers from abroad. He both voiced this *ethos* in his publications and he practiced it, as exemplified by his support of foreign teams who travelled to Portugal to observe the total solar eclipse of 1900.[43] Added to this sense of his mission as a scientist, he likely also harboured a belief in the separation of the scientific and political realms. In practice, Oom managed to affirm the Lisbon Observatory as a republican institution that in its own way contributed to an understanding of the notion of "citizenship" for which science was fundamental.[44]

FUNCHAL: IMPRESSIONS OF AN ATLANTIC ISLAND

On 13 March, astronomers left Lisbon for Funchal where they arrived the next day, coincidentally Einstein's 40th birthday. After a city tour, they had a farewell lunch at a restaurant as Davidson and Crommelin returned to the Anselm heading for Pará, while Eddington and Cottingham stayed in Madeira, waiting for the steamship that would take them to Príncipe. From Pará, Davidson and Crommelin travelled to Sobral, in the interior of the state of Ceará, at that time undergoing an extreme drought, while Eddington and Cottingham were facing a typically tropical climate. Therefore, weather conditions and the odds of success of the two expeditionary teams were quite different between the two locations.

Eddington and Cottingham settled in at Hotel Bela Vista (Jones' Bella Vista), a British-run hotel with many British guests, about a ten-minute walk from the city centre. To overcome the steep slopes of the city, the travellers often resorted to ox-sled carts. They noted the predominance of banana trees, sugar canes, vineyards, palm trees, and cacti. A fruit unknown to them caught their attention: "nesperas [loquats], something like an apricot in appearance but which tastes more like a cherry."[45]

Eddington felt well in Madeira, even though temperatures were high for British standards. The weather was sunny, alternating between desert winds and tropical rains. While Cottingham, already in his fifties and averse to long walks, preferred to socialize in the city, Eddington took the opportunity to go for walks on the island, almost always without his colleague. He climbed the Terreiro da Luta, the Areeiro peak, the Curral das Freiras, and Poiso, Ribeiro Frio, and its balconies. Reaching appreciable altitudes, he sometimes covered more than 25 miles per ride; he enjoyed the levadas (water canals), but disliked the rocky and dirty beaches, even though he often bathed in Ajuda. This was a place recommended to him by a young British man who was in Madeira for treatment, with whom he became friends, took several walks, and played chess.[46]

As for food, Eddington went crazy for the local bananas, eating about a dozen a day, and rated "the meat—mutton, veal and beef—extraordinarily good, the best I ever tasted I think."[47] He also enjoyed the local tobacco.

The two travellers could not resist the casino, where they went for tea almost daily and, of course, to enjoy the thrill of a roulette game. Though it was banned in Madeira, it was still practiced with the complacency of the police and, in their case, with great moderation. Among their interlocutors was an English doctor, the brother-in-law of Lord Kelvin, whose wife belonged to the Madeiran family, the Blandys; at the end of the stay, they met the director of a local newspaper who helped them complete the paperwork to head to Príncipe; after learning the details of the expedition, he published them in his newspaper.[48]

FROM FUNCHAL TO PRÍNCIPE

Eddington and Cottingham spent more than three weeks (precisely 26 days) in Funchal, leaving on 9 April for the city of Santo António, in Príncipe. They travelled aboard the steamship Portugal, of the National Navigation Company, stopping on their way at the island of São Vicente in the Cape Verde Islands, also a Portuguese colony, on 13 April, where one of the largest telegraph submarine cable stations in the world was stationed, and the following day, 14 April, in Praia, on the island of Santiago.[49]

The steamship Portugal was similar in size to the Anselm. It was pleasant and spacious, as was the travellers' cabin. However, there were no rental sunbeds or exercise facilities.[50] About 20 passengers were traveling in first class, including several Portuguese and seven British: in addition to the expeditioners, they included three men heading to the cable station, another heading to a sugar refinery, and a young missionary, to whom they devoted their full attention. There was also a Portuguese naval officer on board who spoke very good English.[51] Leisure activities included a variety of board games, including chess, and small plays as there were actors on board. The food was good, including tender meat and ice cream, though it was not particularly appealing to Eddington who also bemoaned the poor quality of the tea. Once again, there were no signs of rationing: the sugar and butter were plentiful. They ate daily "about as much meat as would have been a week's ration."[52]

The weather was warm, the sky was clear, and there was moonlight until their arrival at São Vicente, an arid and hot island, with temperatures of 29°C in the shade. At this stop, several passengers disembarked the ship and others boarded it. The British expeditioners took the opportunity to visit the cable station, the southern hemisphere's communications hub and a strategic point during the Great War. The next stop was Praia, where the steamship docked for only a few hours. The expeditioners spent Good Friday and Easter Sunday on board, on 18 and 20 April, respectively.

Although they had just passed one of the central communication points between Europe, the United States, and the southern hemisphere (the other was in the Azores), the travellers felt progressively estranged from everything. Since their departure from the United Kingdom, they received little to no news of the international political situation, a situation that had not been mitigated by the rapid passage through Lisbon or the extended stay in Funchal, where newspapers mainly published local news. They were thus headed towards the unknown, near the equator. Their bonds to political time were also fading, and they had no news of their colleagues since their separation in Funchal. They were increasingly anxious.

PRÍNCIPE: IMPRESSIONS OF AN EQUATORIAL ISLAND

As they neared Príncipe, although the ship was only 40 miles away from the mainland, the cloudy weather blocked their view of it. They did see many flying fish and schools of porpoises, but they never spotted whales or sharks.[53] After several days, on 23 April they finally arrived at the village of Santo António.

Portuguese explorers first arrived in the islands of São Tomé and Príncipe in 1470, followed by efforts to settle them over the centuries, with the introduction of sugar cane in the fifteenth century. By the seventeenth century, the culture of these islands was in rapid decline due to competition from Brazil as well as local riots, such that they eventually became not much more than mere slave depositories. United administratively in 1753, by the beginning of the twentieth century, the colony of São Tomé and Príncipe had become a significant world producer of cocoa and coffee.

The travellers' first impressions of the island were very positive. The dense, lush vegetation descending abruptly into the sea contrasted nicely with Cape Verde's aridity.[54] Still on board, the expeditioners were received by Vasconcelos, Príncipe's governor, Grageira, the manager of the Colonial Agriculture Society, and Jerónimo José Carneiro, a young man who had established himself on the island just over two years before, who was the president of the Planters Association, and whose family owned the Sundy plantation (roça Sundy), one of the largest in the area. This formal reception, including all the individuals representing the various official institutions and plantations of the island, left no doubt about the importance accorded by the Portuguese authorities to the travellers and the purpose of their trip. Commenting on their luck, they said, "We soon found that we were in clover."[55] Writing in a more personal register in a letter to his sister, Eddington also added: "The Portuguese here are a very superior type to those we have met before ... Mr. Carneiro is, I believe, very wealthy; he was going to Lisbon early this month, but postponed going especially in order to entertain us."[56]

At the time, it is estimated that the island's population did not exceed 6,000 inhabitants, of which probably no more than 3% were Portuguese or European, with remaining majority being plantation workers.[57] Although slavery had been officially abolished in 1875, the flow of natives from Angola, Cape Verde, and Mozambique coming to work on the São Tomé and Príncipe plantations was tantamount to forced labour, and akin to slavery. This situation gave rise to the conflicts between the Portuguese government and the British authorities in the first decade of the twentieth century, right before the establishment of the republic. The Cadbury family, one of Príncipe's largest cocoa buyers, opposed any business transactions involving "slave cocoa," given the humanitarian concerns of their religious affiliation (as Quakers), beliefs also shared by Eddington.[58]

During the expeditioners' stay on the island, their circle of acquaintances was naturally restricted. In addition to those mentioned above, they included the island's judge, the harbour master, the treasurer, the "curador" responsible for "imported labour,"[59] an employee from the office of Jerónimo Carneiro, and two black British men called Lewis and Wright, the only two workers at the cable station.[60] There was also Atalaia, the manager of Roça Sundy, a former cavalry officer who had fought for the monarchy in 1910 and had gone voluntarily into exile in Spain and France, before taking refuge in Príncipe four years previously. With the exception of Lewis and Wright, few spoke English, and conversations were limited to basic sentences, supported by glances at the dictionary. The close relationship established between Atalaia and Eddington took place in rudimentary French, which was not even within Cottingham's reach, but sufficient to make them understand and even discuss topics of common interest, especially after dinner at Roça Sundy, when workers came to discuss a variety of subjects with Atalaia.

In the small town of Santo António, which they soon referred to as "the city," they were housed at Jerónimo Carneiro's residence, a new villa with a beautiful view of the bay, where a monkey, a dog, and a cat lived together peacefully. They spent four days in the city not only to recover from their long voyage, but also to choose their observational site. They also took a boat ride around the harbour, which included a picnic, and played tennis with the judge and the curador, the only people on the island to practice the sport. They spent their evenings chatting against the backdrop of the sounds of classical music provided by Carneiro's gramophone. Two of the days were used to visit plantations on mule: on the first day, they visited the Esperança and S. Joaquim plantations, and on the second, the Sundy plantation. When they arrived at Sundy, all doubts about the most favourable location for the observations vanished (see p. 121):

> The house is near the north-west corner of the island, away from the mountains, and on a plateau overlooking a bay about 500 feet below. We had noticed this house as we approached the island on the steamer. There was little difficulty in deciding that this was the most favourable spot; and there happened to be an enclosed piece of ground close to the house which just suited us. We look straight on to it from our bedroom window. It is sheltered on the east by a building and is open towards the sea on the west and north—just right for the eclipse. We arranged to have a small pier built for the coelostat to stand on, and to have our belongings brought over on Monday.[61]

Roça Sundy, like all of the island's plantations, was like a small town. It was organized around the administrator's main house, with a chapel, a hospital, workers' housing, offices, warehouses, cocoa drying installations, workshops, stables, and agricultural properties[62] (see p. 132). The space chosen for their observations was located at the rear of the main house; its coordinates were 1º40' N, 29m32s E (7'23" E)[63] (see p. 122). The expeditioners moved to the plantation on 28 April, using mules and a carriage as transport. They were followed by more than one ton of equipment, which was transported by using the plantation's rails. However, for a stretch of about one mile, local workers, numbering about 600 at the time, had to carry it.

With their help, including that of carpenters and mechanics, they began installing the equipment (including tents, the telescope, the celostat, and the regulating mechanism). They constructed two tents, which "stood the deluge splendidly" when barely erected, thus passing a demanding test of nature as to their effectiveness. They decided not to unpack the celostat's mirror, to avoid moisture damage. In a letter to Oom dated 4 May, Eddington acknowledged the invaluable help provided by the locals, adding: "All we need now is a fine day for the eclipse."[64]

As preparatory work advanced at a good pace, their isolation at Sundy led the astronomers to return to Santo António for a week, between 6 May and 13, afterwards returning definitively to Sundy. In this last stage, they completed the installation of the instruments and proceeded to tune and verify them. From 16 May onwards, they took photographs on clear nights, which they also developed at night, because the temperature of the water used to develop them was too warm during the day.

After a period of heavy rain, the Gravana, or the cold season, set in on 9 May. It almost stopped raining, but the sky was cloudy, and the weather seemed much less favourable for observing the eclipse than during the previous rainy season. Eddington likely began to fear for the outcome of the expedition. He must have recalled his team's failure at Passa Quatro as well as that of all the astronomers who in the past had seen their teams' Herculean efforts crowned with disappointment. There were still a few clear days, but the two days preceding the eclipse were the worst of all.

Later, in a letter written to his mother on the return ship to Europe, Eddington's description of the day of the eclipse is a clear and detailed statement that reveals the full spectrum of emotions he experienced in those short moments in which so much work and so many expectations converged:

> On the morning of the eclipse Mr. Carneiro, the Curador, Judge, Mr. Wright and three Doctors came over. Just as they arrived a tremendous rain-storm came on, the heaviest we have seen. It was most unusual at that time of the year; but it was favourable for the eclipse as it helped to clear the sky. The rain stopped about no[o]n (the eclipse was at 2:15[65]). There were a few gleams of sunshine after the rain, but it soon clouded over again. About 1:30 when the partial phase was well advanced, we began to get glimpses of the sun, at 1:55 we could see the crescent (through cloud) almost continuously, and there were large patches of clear sky appearing. We had to carry out our programme of photographs in faith. I did not see the eclipse, being too busy changing plates, except for one glance to make sure it had begun, and another

> half-way through to see how much cloud there was. We took 16 photographs (of which 4 are not yet developed). They are all good pictures of the sun, showing a very remarkable prominence; but the cloud has interfered very much with the star-images. The first 10 photographs show practically no stars. The last 6 show a few images which I hope will give us what we need; but it is very disappointing. Everything shows that our arrangements were quite satisfactory, and with a little clearer weather we should have got splendid results. Ten minutes after the eclipse the sky was beautifully clear, but it soon clouded again.
> We developed the photographs 2 each night for 6 nights after the eclipse, and I spent the whole day measuring. The cloudy weather upset my plans and I had to treat the measures in a different way from what I had intended; consequently I have not been able to make any preliminary announcements of the result. But the one good plate that I measured gave a result agreeing with Einstein and I think I have got a little confirmation from a second plate.[66]

These lines not only tell us precious details about the witnesses in the expeditioners' company who observed the eclipse and most likely helped them in marking the times crucial to the changing and exposing of the plates, but also give us a first assessment of the result of their experiment done under bad weather. The last sentence highlights Eddington's scientific inclinations: "But the one good plate that I measured gave a result agreeing with Einstein and I think I have got a little confirmation from a second plate."

In the same vein, Eddington's telegram to Dyson simply stated: "Through cloud, hopeful."[67] This sentence was in clear violation of a previously agreed-upon protocol on the sentences to be used in the telegrams to express their assessment of results. Despite a huge disappointment, Eddington remained optimistic.

As noted by Eddington, the days following the eclipse were filled with developing and measuring twelve of the sixteen photographic plates; four of them could not be developed *in loco* as their material composition was unsuitable to the local development conditions.[68] In Príncipe, as in Sobral, they relied on local aid, especially on the ice supplied by Grageira to ensure adequate water temperatures for developing the plates.[69] In the meantime, they decided to leave the island without taking extra comparison photographs, due to an impending strike caused by disagreements between the Portuguese government and the shipping company over ticket prices. They chose as comparison plates instead, plates they had previously taken at the beginning of the year in Oxford, under reasonable, but not ideal, conditions.[70]

They spent the remaining days before their departure involved in several activities, including a monkey hunt. Monkeys were so abundant on the island that there were workers on the plantations whose sole job was to drive them out of the cocoa trees. On a trip to one of Sundy's properties, Eddington described a special variety of cocoa planted there: "It was a very fine sight to see the large golden pods in such numbers—almost as though the forest had been hung with Chinese lanterns."[71] On a visit to Lapa, owned by the Colonial Agriculture Society, they visited a beach consisting of a strip of white sand stretching between the coconut palms and the sea, where they swam cautiously on account of sharks, and ate fish on the beach. On a visit to the small island of Bom Bom, they surveyed the ruins of a palace-like building belonging to a well-known woman slave trader.

FROM FUNCHAL TO SOBRAL

The astronomers who travelled to Brazil left Funchal on 14 March and arrived in the city of Belém, the capital of the state of Pará, on 23 March. There are no records of their impressions of life on board, but when they arrived in Belém, their equipment was exempt from customs taxes, thanks to an intervention by the British consul. They chose not to go immediately to Sobral, as it was too early to begin preparations for the big day, and they suspected that no one was yet expecting them. Meanwhile, the Anselm was continuing on to the Brazilian interior, and they heeded the call of adventure. For a little over two weeks, they covered about 1,000 miles through the Amazon rainforest. The Anselm was heading to the city of Manaus, where it was going to pick up goods, including rubber, nuts, cotton, and fibre. In addition to descending into the Amazon River, an extensive expanse of yellowish water, they also sailed the Negro River, whose waters were as black as its name, in stark contrast to the green waters of the Tapajós, which they also sailed. They twice visited the village of Flores by train, and walked on foot in the forest. They saw coffee and pineapple plantations, as well as plant and animal specimens they had never heard of, such as a native plant which "shuts up on being touched,"[72] and "battalions of leaf-cutting ants."[73]

Returning to Belém on 8 April, they contacted the English and American clubs, as well as the American Consul and the director of the tram company, who offered them free trips around the city and surrounding areas. On 24 April, they sailed on the steamship Fortaleza from Belém to Camocim, in the state of Ceará, where they arrived "after a somewhat tedious voyage" on 29 April.[74] They left the next day. The 80-mile train ride that separated them from their final destination crossed an interesting landscape interspersed with mountain chains that contrasted with the bleak landscape of Sobral, a drought-ravaged city of about 35,000 inhabitants. Situated in the interior of the state, just over 150 miles from the capital city of Fortaleza, Sobral was, in its own way, a cosmopolitan city.

SOBRAL: IMPRESSIONS OF A NORTH-EASTERN BRAZILIAN CITY

The warm welcome they received upon their arrival on 30 April, contrasted with the harshness of the natural landscape and the simplicity of the urban milieu.[75] Though local authorities were surprised by the absence of the Jesuit astronomer Cortie (they had not received his message that he could not come), it soon became clear that they would enjoy a special status there.

Morize, the director of the National Observatory of Rio de Janeiro, had carefully prepared everything. He had travelled to Sobral beforehand to secure not only the support of the Brazilian government, but also that of local, civil, and ecclesiastical authorities, represented respectively by mayor Jácome Oliveira and Monsignor Ferreira. Only two people in Sobral could speak English; they were both on the official reception committee welcoming them. One of these, Leocádio Araújo, was an agricultural expert working at the Ministry of Agriculture, who escorted the astronomers during their stay, acting as an interpreter and supporting them in their work. A motorcar from Rio de Janeiro was also made available to them, and was used for various tours, in particular to Meruoca Mountain, six miles away from Sobral, a plateau where local elite members spent warm days. Hence, in addition to being recognized as world-class experts, the astronomers were also treated as very important tourists.

The British expeditioners stayed in the home of the deputy of Sobral, Colonel Vicente Saboya, along with the magnetic observers Daniel Wise and Andrew Thomson of the expedition organized by the Carnegie Institution of Washington, D.C., in the United States. They were interested in earth magnetism and atmospheric electricity, and for reasons of stability, their measurements were carried out partly in the home's basement.[76] As the wealthy owners of a cotton factory, the Saboya family's high status was reflected in perks that included, among others, access to piped water in their homes and properties, a luxury not afforded to most locals.

The visitors had little difficulty in selecting the racecourse of a nearby Jockey Club (Clube Hípico) as their observational site (see p. 182). Conveniently located just in front of the house where they were staying, it was not going to be used during their stay, and had a hard, slightly sandy soil, which was less likely to become dusty, therefore less unfavourable to the proper functioning of the instruments. Its large covered tribune allowed them to unpack their instruments in the shade, and with the help of local workers, including masons and carpenters, to build pedestals for the celostats and astrographic telescope, with grooves on the upper surface to enable their rotation. As with their colleagues in Príncipe, the shelter they prepared for the instruments was tested, not by torrential rain, but by a very strong gust of wind. Unlike the Príncipe shelter, it did not pass the test and had to be rebuilt by local carpenters with wood intended for building a darkroom, which was not needed in the end.

Morize's team finally arrived on 9 May to make astrophysical observations. It included seventeen people from the National Observatory of Rio de Janeiro, including two assistants, a calculator, a meteorological assistant, a mechanics assistant, an assistant carpenter, and a chemist from the Geological and Mineralogical Service of Brazil (Serviço Geológico e Mineralógico do Brasil).[77] Three team members brought their wives and some other family members.

In addition to being director of the National Observatory, Morize was also the first president of the Brazilian Academy of Sciences, which he helped to found in 1916. The creation of this institution was part of a movement that had emerged in Brazil in the early decades of the twentieth century and had gained momentum with the upcoming centenary of Brazil's independence in 1922. Together with other colleagues, Morize worked towards affirming a scientific research *ethos* in Brazil which recognized its importance for society irrespective of its practical applications, and promoted the consolidation of a cohesive and autonomous scientific community.

His willingness to support the British astronomers visit, to provide them with all necessary help on-site and by developing an observational program in astrophysics at their side, was a full demonstration of his willingness to affirm science in Brazil, both nationally and abroad. No wonder he insisted on a detailed photographic record of their stay at Sobral, which included several photographs of his team, some of which were taken with Crommelin and Davidson, as well as with the American observers.

At the same time, Morize ensured that there would be ample journalistic coverage of all activities associated with the observations of the eclipse, and with the foreign travellers' stay. The local newspapers of the states of Pará and Ceará were lavish in their reporting, which helped disseminate Einstein's theories in the Amazon region and in North-eastern Brazil for the first time. Newspaper coverage took place in other states too, particularly in Rio de Janeiro, then the country's capital. This coverage presented both Einstein and Brazilian astronomy to the Brazilian general public, introducing the latter into the public sphere by giving it increased visibility.[78]

As in Príncipe, the day of the eclipse did not look very promising in Sobral. At the time of first contact, 90% of the sky was cloudy. The few sunny moments allowed them to make the necessary equipment adjustments in order to observe neighbouring stars. According to Crommelin's report,

> A large clear space in the clouds reached the Sun's neighbourhood just in time, and for four out of the five minutes of totality the sky near the Sun was quite clear. For one minute after mid-totality there was thin cloud in this region; this, while hiding the stars, gave well-defined images of the inner corona and prominences, so that our photographic record of these is scarcely less complete than if we had specially endeavoured to secure them.[79]

During the eclipse, Leocádio Araújo was in charge of the metronome to indicate when to expose the photographic plates at the stipulated times. Nineteen plates were exposed on the astrographic telescope, with alternating five- and ten-second exposures, and eight plates on the four-inch telescope, with a uniform exposure time of 28 seconds.[80]

Unlike Eddington, Crommelin did not violate the pre-established communication protocol with Dyson and used the sentence agreed upon to state promising results. The telegram that Crommelin sent Dyson stated: "Eclipse. Splendid."[81] However, as in Príncipe, in Sobral time played tricks on the observers, albeit in a veiled way. The astronomers did not know it yet, but the development of the plates would reveal that the extreme heat had dilated the larger celostat, and thus had distorted the star images captured by the astrographic telescope.

The following nights, Davidson developed the plates using local clay pots to ensure adequate water temperature; he dipped them in containers with a solution that guaranteed proper conditions. While the expeditioners brought instruments built with pre-existing components adapted from wartime to the conditions of the observational sites, they also temporarily used daily objects they found *in loco* as auxiliary scientific instruments. Thus, the accuracy of the measurements resulted not from state-of-the-art technologies, but from a combination of technologies-of-use and household objects.

After the eclipse, Davidson and Crommelin wanted to provide extra time for the production of comparison plates. So while they waited, they visited the state capital, the coastal city of Fortaleza, where the climate was much milder than that of Sobral. They stayed a little over a month, between 7 June and 11 July, staying by invitation at the Seminary, a Catholic institution of the ecclesiastical formation of the Archdiocese of Fortaleza.[82] The fact that they were Catholic astronomers opened this door, allowing them to overcome the challenge of the overcrowding of the city's hotels. No doubt, the travellers remembered how difficult it had been to find a hotel in Liverpool, at the beginning of their adventure.

Returning to Sobral, between 11 and 18 July, they obtained the comparison plates. Disassemblage, storage, and packaging of the material occupied them until 21 July.

THE TRAVELLERS' RETURN HOME

With official help, Eddington and Cottingham secured a place in the overcrowded S.S. Zaire, departing on 12 June from Santo António with Jerónimo Carneiro. They shared a cabin with another Portuguese man, met again the young missionary with whom they had travelled on the Portugal, as well as another Quaker missionary.

The return was worse and slower than the inbound trip. It was eased a bit by a telegram from Dyson stating: "the Brazil party had been successful."[83] While the telegram sent by Crommelin to Dyson followed the pre-established code, and indicated a perfect eclipse, Eddington's broke with the protocol, maintaining some hope, despite the disappointment.[84]

They passed again by the city of Praia, in Cape Verde, on 20 June, and arrived in Lisbon on 2 July.[85] They departed from Lisbon aboard another overcrowded steamship from the Royal Mail Steam Packet Line, arriving in Liverpool on 14 July.[86]

Meanwhile, back in Brazil, after obtaining the comparison plates, Davidson and Crommelin packed their equipment and left Sobral. They returned to Camocim, where they departed on 22 July on the ship Fortaleza to Belém. They arrived on 28 July. They left for Maranhão on 31 July on board of the steamship Ceará, and then headed to Liverpool aboard the Polycarp.[87] On 25 August, they were back in the United Kingdom, more than a month after Eddington and Cottingham had arrived.

OBSERVATIONS, INVISIBILITIES, AND SILENCES

Several months of uncertainties and expectations converged during a mere 302 seconds of the eclipse's totality. These included travel planning, choosing routes, certifying foreign support from local communities and authorities, assembling instruments with pieces from various observatories, choosing the expeditioners, arriving at the observation sites and choosing the suitable place for mounting, preparing, and testing the instruments. It is not surprising, then, that the bustle, excitement, and expectations of the mission described in private communications offer spontaneous and thrilling testimonies, which often contrast the restrained style of public accounts.

To the best of our knowledge, only Eddington produced both private and public accounts of the expedition. Of these, the 1920 article co-authored with Dyson and Davidson provides a detailed analysis of the observations.[88] It describes in detail the characteristics of the selected sites, the experimental setup (of which there is only one photographic record in the case of Sobral and none in the case of Príncipe), as well as the results obtained and the calculation of the deflection value. This account not only reflects Eddington's excellent communication style, but also his need to simply and accurately explain the measurements, especially since the weather did not cooperate as expected. Many plates showed a spectacular prominence, as if it were the solar crown that British astronomers wanted to study; however, with the exception of a small set of plates, they did not reveal any stars.

Not surprisingly, there are significant differences between the description included in the joint article and the private account expressed in the letter Eddington wrote to his mother on his return to Europe, transcribed above. Though the information provided is roughly the same, the article differs from the letter in its greater precision in identifying the moments of totality, and, mainly, by its absence of emotion.[89] The public description mentions the excellent quality of the photographs and the notability of the solar prominence, but omits references to any disappointment caused by the bad weather, their blind faith in believing in the program's execution, and their hope that the results would prove Einstein's prediction.

It is also curious to note how Eddington refers to the eclipse also in 1920 in his book *Space, Time and Gravitation*, cited above, a non-technical account that introduces the lay public to the formalism and conceptual apparatus of the theory of relativity. The volume devotes two chapters to GRT predictions, and one chapter, titled significantly "Weighing Light," to a description of the expeditions and their results. Eddington apologizes to the reader for the chapter's experimental subject, despite the book's fundamentally theoretical bias, justifying it on account of its relevance. He describes in poetic terms the magical moment of totality, as one of enormous beauty, expectation, and bustle:

> Our shadow-box takes all our attention. There is a marvellous spectacle above, and, as the photographs afterwards revealed, a wonderful prominence-flame is poised a hundred thousand miles above the surface of the sun. We have no time to snatch a glance at it. We are conscious only of the weird half-light of the landscape and the hush of nature, broke by the call of the observers, and the beat of the metronome ticking out the 302 seconds of totality.[90]

In terms of the content of written accounts, this demonstrates the slow decline in his emotional expression from the richness of his private communication, which exposed his true feelings, to a scientific textbook intended for popular consumption, which passionately describes the landscape and the environment, but omits references to his inner feelings, and, finally, to a scientific paper, centred on factual, detailed, and technical information.

In the joint article, the authors state that "exposures were made according to the prepared program foreseen, and 16 plates were obtained. Mr. Cottingham gave the exposures and attended to the driving mechanism, Prof. Eddington changed the dark slides."[91] Thus, the article omits any reference to the local witnesses who assisted the expeditioners in their work, but who are included in Eddington's letter to his mother: "Mr Carneiro, the Curador, Judge, Mr Wright and three Doctors came over." The attentive reader of *Space, Time and Gravitation* may also spot a reference to the "observers," who at appropriate times, gave the fundamental indications for the plate changes. They could include the participants mentioned above.

Crommelin produced an individual public account in a paper titled, "The Eclipse Expedition to Sobral," whose content was partially transcribed in a section sharing the same title in the joint article by Dyson, Eddington, and Davidson.[92] In fact, several paragraphs are the same, although this article was not signed by Crommelin, only Davidson. As for the description of totality, I mentioned above in the section titled, "Sobral: Impressions of a North-Eastern Brazilian City," that British astronomers were helped by Leocádio Araújo, who was in charge of the metronome, in order to indicate to them the stipulated exposition times for the photographic plates. This reference appears not only in Crommelin's article but also in the joint article:

> When the crescent disappeared the word "go" was called and a metronome was started by Dr. Leocádio, who called out every tenth beat after totality, and the exposure times were recorded in terms of these beats. It beat 320 times in 310 seconds; allowance has been made for this rate in the recorded times.[93]

A cross-reference of different sources reveals that both in Príncipe and in Brazil, the expeditioners observed totality in the company of other participants, some of whom held prominent functions. Thus, despite their invisibility, two types of local actors participated directly in the experiments in both Sobral and Príncipe: the workers who provided the manpower to build supports for the instruments or protective structures of the whole apparatus, and the members of the local elite who participated in the observations of totality. These were joined by national and colonial astronomers, authorities and individuals who, in both cases, ensured the success of their travels, as well as their hosting and accommodations during their stopovers and stays in Lisbon, Funchal, Sobral, and Príncipe.

In addition to these actors' invisibility, was the inexistence of photographs of the experimental apparatus itself, and of travellers in Príncipe. By contrast, such images do exist of the Sobral trip, including a photograph taken by Davidson of the experimental equipment, and several photographs of the expeditioners. The existence of visual records in Sobral and their absence in Príncipe were probably due to the asymmetry of geographical, material, and human conditions in both places. The contrast between a second city in a Brazilian state and an important plantation on a small island, far from the metropolis of an extended colonial empire, is striking. It is no wonder that three expeditionary teams observed in the north-eastern Brazilian city, while only two observers made it to the equatorial island.[94]

Although there is no visual record of the apparatus used at Príncipe, given that both the wooden structures and the canvas to protect the instruments were jointly prepared in Greenwich, it seems likely that it must have been similar to that at Sobral, with the omission of Cortie's telescope and accompanying nine-inch celostat[95] (see p. 168).

As for the extant photographs of the expeditioners, Davidson and Crommelin appear integrated within the group, in pictures of the Brazilian team members, which often also include several women (see p. 182). But in contrast to their Brazilian counterparts, the British astronomers are in prominent positions and are wearing white suits. The existence of this visual record shows that Morize was invested in having a detailed photographic report of the team of the National Observatory of Rio de Janeiro, showing them at different moments, and in different contexts and settings. This was part of a consistent strategy of national and international affirmation of Brazilian astronomy, which was reinforced by the presence of reputed British astronomers among Brazilian peers.

There are two other invisibilities associated with the written records, both of which relate, directly or indirectly, to Portugal as a colonial power and the accusations of slave labour in its African possessions.

One of these is the invisibility of Portugal in most of the written reports, with few exceptions. This results from the identification of Príncipe by its geographical location on the west coast of Africa, thereby undercutting its colonial status and avoiding its undesirable political connotations with the practice of slavery. One exception is the account of the Royal Astronomical Society meeting of 9 March 1917, in which Dyson discussed the possibilities offered by the 1919 eclipse and presented Príncipe as "a well-developed Portuguese island which became celebrated a short time ago owing to the politicians' interest in 'slave cocoa'."[96] In this presentation and its minutes, restricted to an astronomically-minded circle of readers of the journal *The Observatory*, there is an explicit mention of Príncipe's colonial status and its existing labour conflicts. The other exception is the much more widely disseminated 1920 joint article, which reports the results of the two expeditions, and specifies that "Príncipe is a small island belonging to Portugal, that lies just north of the equator in the Gulf of Guinea, about 120 miles from the African coast."[97] The reference to Portugal, perhaps deliberately omitting the words "slave cocoa," is particularly brief. Even in the final acknowledgments, there are no thanks to the Portuguese government, only to Carneiro (and Atalaia), therefore, on an individual basis and not as members of colonial institutions. By contrast, in the case of Sobral, the support and hospitality of the Brazilian government is recognized in the acknowledgments.

The other invisibility is Eddington's omission in letters and publications of working conditions in the plantations (roças) and of "slave cocoa." Only at first glance could this silence seem strange, given the religious convictions Eddington shared with the Cadbury company, and the opposition of the British government to the Portuguese authorities a decade before, the tenacious echo of which still reverberated during his stay in Príncipe. The ethical values instilled in Eddington by his education in the markedly class-based British society, as well as the behavioural expectations in host-guest relationships may explain the absence of this subject in both his private and public accounts.

This perspective is complemented by a view of science and the scientific *métier* engineered by scientists themselves, at least since the seventeenth century, which placed them at odds with the real world in which they worked. This was, moreover, the vision that underlies Eddington's passionate strategy, which constitutes an instance of what we might call informal science diplomacy.[98] He endeavoured to present the expeditions as the quintessential instance of scientific internationalism, all the more captivating as it took place against a political backdrop of war and conflict between the home countries of the astronomer who measured deflection, and the physicist who predicted it. His narrative clearly highlights the attractive contours of this vision and its role in building a community (of scientists) committed to affirming their importance and socio-professional status. With all these points in mind, the invisibility of the existence of "slave cocoa" remains uncomfortable, but is not surprising. It is a sign of the times, a reflection of narrative accounts, and the mythologies constructed by a community.

EXPECTATIONS AND PUBLIC ANNOUNCEMENT

The four travellers' return to the United Kingdom may have completed the trip, but it was still not yet over. It was necessary to compare the stellar positions recorded on the plates taken during the eclipse with those of the comparison plates and to accurately calculate the deviation values to check whether or not they satisfied Einstein's prediction. This was to be followed by a public presentation, and a discussion within the scientific community that would validate the astronomers' conclusions and sponsor their results. As we know, results can only be scientifically accepted when they are no longer the property of a few, but belong to everyone, a process that takes its time. Understanding the meaning and implications of the observational results proved to be an even slower and more complex process than the former one.

Data analysis lasted throughout the summer. The process was closely monitored by members of the Royal Astronomical Society, who were briefed by Dyson on its progress. Concerning Sobral's astrographic telescope, of the nineteen plates, three showed at least seven stars, and sometimes as much as twelve stars; seven of the eight plates taken with Cortie's telescope revealed seven stars.[99] Of the sixteen plates taken in Príncipe, with exposures between two and twenty seconds, only two registered five stars.[100] Meanwhile, Einstein was waiting expectantly.[101]

Through Dutch friends, possibly Hendrik Lorentz (1853–1928) or Paul Ehrenfest (1880–1933), Einstein received the first news shortly after the eclipse. In a letter sent to his mother in June, he wrote that a Dutch newspaper (possibly based on news from *Nature* and *The Observatory*) reported that expeditioners were successful despite the clouds, and that results should be announced within six weeks.[102] On 21 July, the newspaper *Vossische Zeitung*, which had already published an article titled "The Sun will Bring it all Out" on the actual day of the eclipse, briefly referred again to the two expeditions.

In the meantime, news from the United States was disappointing. On the one hand, Campbell announced the inconclusive results of

Curtis's observation of the total solar eclipse of 8 June 1918. On the other, spectroscopist Charles Edward St. John (1857–1935) of the Mount Wilson Observatory in California revealed negative results concerning the detection of the gravitational redshift, the third prediction of GRT, which Freundlich also tried unsuccessfully to detect several years before.[103]

Without further news, by mid-September, Einstein's concerns were mounting, evidenced in a letter he sent to Ehrenfest. Finally, on 22 September he received a telegram from Lorentz stating that "Eddington found star dislocation at solar rim provisional magnitude between nine tenths second and double,"[104] a range that fitted the displacement between 0.9" and 1.8" seconds of arc. Despite uncertainty regarding the final value, this range accommodated Einstein's prediction. This much he announced in letters to his mother and to colleagues, as well as to a journalist. Shortly afterwards, Max Planck congratulated him on the good news of Lorentz's telegram: "You yourself have frequently observed that you had no doubt about the result, but it is a good thing that this fact has now been established beyond doubt by others."[105] On 8 October 1919, an article in the *Berliner Tageblatt* stated that the results confirmed Einstein's prediction and that relativity represented the true structure of the universe. It was not until late October, when he visited Leyden that Einstein began to relax. In a letter to Planck, he revealed that Ejnar Hertzprung (1873–1967) showed him a letter from Eddington asserting that rigorous plate measurements confirmed the theoretical value of light bending. Relieved, he commented, "It is a mercy of fate that I was allowed to see this."[106] When he returned to Berlin, the good news had preceded him, and many congratulated him.

The public announcement took place a few days later, on 6 November 1919, at the joint meeting of the Royal Society of London and the Royal Astronomical Society. We know in some detail what happened at Burlington House, then the headquarters of the Royal Society. The minutes of the meeting not only summarize the scientific debate but also allow us to sense the atmosphere, and even to foresee the impact of the results.

Joseph John Thomson (1856–1940), the President of the Royal Society, immediately gave the floor to Dyson, who explained the context of the expeditions, the measurements and calculations made, and the figures obtained. He then gave the floor to Crommelin and Eddington to present the full details of the expeditions to Sobral and Príncipe, respectively. The results presented were 1.98" ± 0.12 seconds of arc for Sobral and 1.6" ± 0.3 seconds of arc for Príncipe, compatible with the value predicted by Einstein (1.75" seconds of arc).

Both Thomson, and Fowler, President of the Royal Astronomical Society, supported their conclusions. Recalling that in the first

Query of *Optics*, Newton assumed that bodies could act on light, and that such a suggestion led to a value of deflection that was half that predicted by Einstein, Thomson was blunt:

> This is the most important result obtained in connection with the theory of gravitation since Newton's day, and it is fitting that it should be announced at a meeting of the society so closely connected with him.
> [...] If it is sustained that Einstein's reasoning holds good—and it has survived to very severe tests in connection with the perihelion of Mercury and the present eclipse—then it is the result of one the highest achievements of human thought.[107]

A new theory of gravitation was taking its first steps in the home of Newton, and it seemed to be a superlative theory, "one of the highest achievements of human thought." Like Astronomer Royal Dyson, Thomson, another patriarch of British science, emphasized the victory of the theory of relativity in justifying the advance of Mercury's perihelion, which though certainly less spectacular than the validation of light bending, was still comforting for finally justifying a well-known fact that had persistently challenged decades of explanatory attempts.[108]

The ensuing debate included interventions by Eddington, A.F. Lindemann (1846–1927), H.F. Newall (1857–1944) and L. Silberstein (1872–1948), and addressed objections to light bending or to its interpretation, as well as suggestions for explanatory alternatives advanced by sceptics like Silberstein and Newall. It also assessed the significance of accepting a law of deflection of light in terms of a new theory of gravitation, or the need to accentuate the physical character of the new theory as opposed to its mathematical formalism. These were aspects highlighted by its advocates, namely, Eddington and Lindemann. Thus began a long and arduous process towards the understanding and acceptance of the theory of relativity. This was all the more difficult, as the foundations of the new physical theory challenged the understanding of experts and lay people alike. Furthermore, its mathematical apparatus, based initially on the "theory of invariants and . . . the calculus of variations," was a source of doubt even for experts, as Thomson and Lindemann rightly pointed out.[109] No wonder historian of science Matthew Stanley recently dubbed this long process the "Einstein War."[110]

As the president of the Royal Astronomical Society and the Astronomer Royal suggested, further confirmation was needed to consolidate such an important result. In the following years, attempts at reconfirming light deflection took place, starting with the total solar eclipse of September 1922 in Australia. Alternatives to circumvent the occurrence of eclipses were also explored through the development of diurnal techniques of photography of stars near the sun, following initial experiments by Lindemann. Attempts to verify the gravitational redshift, Einstein's third prediction, also continued.

At the same time, close scrutiny of Eddington's data reduction work began. Eddington was, no doubt, inclined to confirm Einstein, as he soon confessed in the book *Space, Time and Gravitation*, admitting that he "was not altogether unbiased."[111] But inclination towards a result is not equivalent to data manipulation. On this point, one should mention that the most important data analysis decisions were made by Dyson, who was somewhat neutral towards relativity as a physical theory, but sensitive to its astronomical consequences. He recognized its ability to explain the anomaly of Mercury's movement and admitted an enormous interest in exploiting its potential. In fact, his handwriting appears in several important passages in Sobral's data reduction notes, while Eddington's handwriting appears nowhere.[112] Noting that at Sobral, the main telescope with the astrographic lens lost focus during the eclipse due to overheating of the celostat,[113] Dyson decided to ignore the results obtained with this telescope (0.93" seconds of arc), which seemed to favour Newtonian physics. They were reduced to the observations obtained with Cortie's telescope, which had a smaller view field than the astrographic lens. Subsequently, Dyson reanalysed the plates taken by the astrograph and obtained a deflection value of 1.52" seconds of arc (without error indication), very close to Einstein's prediction.[114]

Six years after the joint session, Alfred North Whitehead (1861–1947) compared the events of that memorable day with those of a Greek tragedy:

> The whole atmosphere of tense interest was like that of Greek drama. We were the chorus, commenting on the decree of destiny in the unfolding development of a supreme incident. There was dramatic quality in the very staging—the traditional ceremonial and in the background the picture of Newton to remind us that the greatest of scientific generalizations was now, after more than two centuries, to receive its first modification.[115]

No one forgot the dense atmosphere accentuated by the unexpected departure of Sir Oliver Lodge (1851–1940), a leading figure of British science and a fierce advocate of ether physics who was strongly opposed to the new theory of gravitation. His retreat was interpreted as a vehement demonstration of his allegiance to old Newton and his repudiation of Einstein.[116] No one wanted to acknowledge that Lodge left the hall, as he confirmed the next day to *The Times*, "due to a long-standing engagement and a 6 o'clock train."[117]

In both scientific and journalistic articles, the results were presented as a confrontation between Newton, the quintessence of classical physics, and Einstein. The latter was beginning to draw the attention of the broader scientific community beyond a narrow circle of German physicists, while simultaneously emerging as a public figure. Two alternative theories of gravitation were opposed, the last of which was based on a drastic reconceptualization of the foundations of classical physics and its notions of space, time, and matter. Many were unable to understand or unwilling to accept it. *The Times* of London, dated 7 November, expressed this state of affairs with the sensational headline "Revolution in Science. New theory of the universe. Newtonian ideas overturned,"[118] followed by a summary of the previous day's session at the Royal Society.

Following scientific protocol, Thomson's statement omitted any mention of the political context, its negative implications for scientific international relations, and Einstein's and Eddington's nationalities. The same was true in the first news on the subject in *The Times*, on 7 November. Things changed subsequently. Taking advantage of the post-war climate, an article dated 8 November omitted Einstein's dual Swiss-German nationality, and presented him as a liberal-minded Swiss Jew and, moreover, as one of the signers of the counter-manifesto to the German Manifesto supporting the war, published in 1914.[119] As already mentioned, the manifesto was endorsed by reputed German scientists who had thus given the support of German science to the military intervention of their government. On 28 November in the same newspaper, Einstein acknowledged that:

> After the lamentable breach in the former international relations existing among men of science, it is with joy and gratefulness that I accept this opportunity of communication with English astronomers and physicists. It was in accordance with the high and proud tradition of English science that English scientific men should have given their time and labour, and that English institutions should have provided the material means, to test a theory that had been completed and published in the country of their enemies in the midst of war.[120]

Despite Einstein's repudiation of many German values, including those underpinning the nation's belligerent attitude, he exposed the newspaper's omission of his dual nationality, and the impact of war on scientific international relations and communication. As a staunch pacifist on ideological grounds, he could not resist adding:

> The description of me and my circumstances in the *Times* shows an amusing feat of imagination on the part of the writer. By an application of the theory of relativity to the taste of readers, today in Germany I am called a German man of science, and in England I am represented as a Swiss Jew. If I come to be regarded as a *bête noire*, the descriptions will be reversed, and I shall become a Swiss Jew for the Germans and a German man of science for the English![121]

Einstein used an exquisite metaphor legible to all in order to highlight the relationships between science, politics, and religion, and how divergent formulations supported contradictory perspectives. However, the editorial note accompanying the issue reacted negatively to this comment.

Following the public presentation on 6 November, news spread rapidly around the world. Einstein was catapulted to scientific stardom, in a trajectory typical of the twentieth century. With the growing presence of the press and of the new media, it became an integral, albeit complementary, part of the process of the construction and communication of the sciences. The same happened with Eddington, though on a more circumscribed scale. Contrary to astronomical practice on both sides of the "barricade," his mastery of communication led him to use the expeditions as an example of scientific cooperation and internationalism, above political divisions and nationalist frictions.[122] In the end, the eclipse of 29 May 1919 also acquired stardom status in the universe of total solar eclipses.

The announcement did not just have an immediate effect on the lives of the main protagonists of this narrative—Einstein and Eddington. It also affected the lives of other travellers and scientific communities (physical, astronomical, and also mathematical), who appropriated the results of the expeditions (especially Einstein's theory), and reacted to them in different forms and at different times depending on their local contexts and their scientific agendas, a topic that is outside of the scope of this essay, but which merits further research.

CONCLUSION

By simultaneously taking into consideration different types of sources, and by comparing public ones from scientific publications to newspaper articles, with private ones, I have offered a detailed analysis of the British expeditions to Sobral and Príncipe. I have discussed their preparation, travels, and results, and the initial impact of their observations. Jointly, they evidence close relationships not only between astronomy, politics, religion, and colonial empires, but also between scientists, communities, and institutions, some more powerful and more visible than others, but all determinant for the construction of knowledge.

Although such sources are partial and of very different formats and lengths, the private and public reports by travellers of their adventures intertwine personal impressions and subjective comments with scientific considerations, in some cases complementing and even clarifying central aspects of scientific publications.

Taken together, these sources have enabled the reconstruction of the lively experiences of two celebrated astronomical expeditions, highlighting their multiple scientific, social, political, and even religious facets. They also reveal the constant setbacks, the unexpected and long-awaited successes, the persistence and renunciation, and the unforeseen role of contingencies. Finally, they help clarify the complexity of the scientific process, challenging the pitfalls of linear narratives and anachronistic assessments.

By comparing travellers' reports with locally-produced ones from astronomers, elites, journalists, or the general public, in the near future it will be possible to contrast perspectives, and move towards a more complete reconstruction of such expeditions as social and cultural encounters. Local accounts exist for Sobral, but are absent for Príncipe. Once again, this asymmetry may be the result of the disparate geographical and geopolitical conditions of the two observational sites.

Ultimately, the complexity of the historical past will only be deconstructed when we scrutinize the two British expeditions in full detail, rather than focusing on facets of this history, centred on partial national contexts, however important. This shift in perspective will enable us to move towards what I call a global history of the 1919 eclipse with respect to the theory of relativity. This is one of the most compelling historical tasks offered by revisiting the various complementary past histories of this famous eclipse.

ACKNOWLEDGMENTS

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ENDNOTES

Archives:

PT/MUL/OAL - Arquivo Histórico dos Museus da Universidade de Lisboa, Observatório Astronómico de Lisboa, Universidade de Lisboa.

TCL: EDDN A4/2 - Trinity College Archives, Eddington Correspondence. Letters from Eddington to mother/sister.

Notes

1 F.W. Dyson, A. S. Eddington, C. Davidson, "A determination of the deflection of light by the sun's gravitational field, from observations made at the total solar eclipse of May 29, 1919," *Royal Society of London, Philosophical Transactions* (1920), A220, 291–333, translation in A.M. Nunes dos Santos, Christoffer Auretta, eds., *Eddington e Einstein* (Lisboa: Gradiva, 1992).

2 Among Einstein's various biographies, Abraham Pais's *Subtle is the Lord. The science and life of Albert Einstein* (Oxford: Oxford University Press, 1982) is recommended, or at a more elementary level, Albrecht Fölsing, *Albert Einstein* (Penguin, 1997).

3 The unfounded conjectures about Mileva Maric's participation in the genesis of SRT are taken up in Allen Esterson, David C. Cassidy, *Einstein's Wife: The Real Story of Mileva Einstein-Maric* (Cambridge, Massachusetts: The MIT Press, 2019).

4 Jeffrey Crelinsten, *Einstein's jury. The race to test relativity* (Princeton: Princeton University Press, 2006); summary in Ana Simões, "O eclipse de 29 de Maio de 1919 e a teoria da relatividade. Um encontro improvável," *Gazeta de Física* 42(2) (2019), 4-7.

5 TCL: EDDN A4/2, letter to mother, 26 September 1912.

6 This suggestion has already been made by John Stachel in "Eddington and Einstein" in *Einstein from B to Z* (Birkauser, Boston, 2002), p.455.

7 A. S. Eddington, "Some problems of astronomy. XIX. Gravitation," *Monthly Notices of the Royal Astronomical Society* 38 (1915), 93. See Stachel, "Eddington and Einstein" (ref.6) and, for Eddington's biography, Matthew Stanley, *Practical mystic: religion, science and A.S. Eddington* (Chicago: Chicago University Press, 2007).

8 Letter from Eddington to Sitter, 4 July 1916, referred to in John Stachel, "Eddington and Einstein" (ref. 6), p.456.

9 A.S. Eddington, *Report on the Relativity Theory of Gravitation* (London: Fleetway Press, 1918, 2nd edition 1920); *Space, Time and Gravitation. An Outline of the General Relativity Theory* (Cambridge: CUP, 1920); *The Mathematical Theory of Relativity* (Cambridge: CUP, 1923).

10 According to Stachel, "Eddington and Einstein" (ref. 6) pp.456-7, Dyson was aware of the article written by astronomers Lindemann, father and son, who in 1916 used a special photographic technique they invented to photograph stars close to the sun, thereby circumventing the occurrence of eclipses. Apparently, the meeting between Lindemann's father and Einstein in Brussels in 1913 provided the occasion to discuss light bending.

[11] F.W. Dyson, "On the opportunities afforded by the eclipse of 1919, May 29 of verifying Einstein's theory of gravitation", in "Minutes of the Meeting of the Royal Astronomical Society", *The Observatory. A Monthly Review of Astronomy* 40 (512) (1917), 153-157, 153-154.

[12] Dyson, Eddington, Davidson, "A determination" (ref. 1), p. 291; Jean Eisenstadt, A.A. Passos Videira, "A Relatividade Geral Verificada: O Eclipse de Sobral de 29/05/1919," in Ildeu Castro Moreira, A.A. Passos Videira, eds., *Einstein e o Brasil* (Editora UFRJ, 1995), pp. 77-99, pp.86-88.

[13] Sobral, in the state of Ceará, Brazil; S. Paulo rocks, on the Atlantic coast of Brazil; Cape Palmas, Liberia; Island of Príncipe; Libreville, capital of the then French Congo, now Gabon; west of Lake Tanganyika; Lusaka, Zambia. In Dyson, "On the opportunities" (ref. 11), pp. 154-156.

[14] Dyson, "On the opportunities" (ref. 11), pp.154-155.

[15] Ayres de Barros, "A acção da Sociedade de Geografia de Lisboa na programação da missão de Eddington à Ilha do Príncipe em 29 de Maio de 1919," in *Comemorações do 90º aniversário da expedição científica de Eddington à ilha do Príncipe* (Lisboa, SGL, 2010) in pp.9-27.

[16] Frederico Oom, "O eclipse total do Sol em 29 de Maio de 1919 visível na Ilha do Príncipe", *O Instituto* 64 (1917), 97–8.

[17] Dyson, Eddington, Davidson, "A determination" (ref. 1), p.295, Eisenstadt, Videira, "A Relatividade Geral verificada" (ref. 12), p.93. For more information on the stay at Sobral see Joyce Mota Rodrigues, *Entre telescópios e potes de barro. O eclipse solar e as expedições em 1919/Sobral-CE*, Tese de Mestrado, Fortaleza, 2012; A.A. Passos Videira, ed., *Henrique Morize e a causa da ciência pura no Brasil* (Zit Editora, 2012); L.C.B. Crispino, M.C. de Lima, "Amazonia introduced to general relativity: The May 29, 1919, solar eclipse from a north-Brazilian point of view," *Physics in Perspective*, 18(4) (2016), 379-394.

[18] At current pound rates, £ 48000 were granted for travel and around £ 4800 for equipment, totalling approximately € 58600. See https://fxtop.com/pt/calculadora-de-inflacao.

[19] Dyson, Eddington, Davidson, "A determination" (ref.1), p. 295. Tom Ray identified the current location of this celostat. See https://podcasts.ox.ac.uk/einstein-lens-and-tale-two-eclipses.

[20] Pedro Raposo, *O gigante da Tapada. Campos Rodrigues (1836-1919) e o Observatório Astronómico de Lisboa* (Lisboa: Imprensa da Universidade de Lisboa, 2019).

[21] PT/MUL/OAL/C/240, Correspondence from Eddington to direction of OAL (mostly addressed to F.T. Oom), letters 11 November 1918, 21 December 1918, 14 January 1919, 8 February 1919, 26 February 1919, 25 March 1919, 4 May 1919, and 3 August 1919. The analysis of the impact of Príncipe's expedition on astronomers' practices was analysed in Elsa Mota, Paulo Crawford, Ana Simões, "Einstein in Portugal: Eddington's expedition to Príncipe and the reactions of Portuguese astronomers (1917-1925)," *British Journal for the History of Science*, 42 (2009), 245-73.

[22] Luís Miguel Carolino, Ana Simões, "The eclipse, the astronomer and his audience: Frederico Oom and the total solar eclipse of 28 May 1900 in Portugal," *Annals of Science*, 69 (2) (2012), 215-238; Luís Miguel Carolino, Ana Simões, "Frederico Oom e a promoção da astronomia em Portugal," *Gazeta de Física* 42(2) (2019), 17-20.

[23] PT/MUL/OAL/C/240, letter 11 November 1918.

[24] Oom, "Eclipse Total" (ref. 16). We do not know if there were delays in the journal's arrival at the OAL due to the war. However, it is unlikely that by November 1918, the journal's issue including Dyson's article had not arrived yet at the OAL (unless it was not even sent). In all correspondence exchanged with colonial entities the scientific importance of the event is mentioned, but there is never any reference to Einstein's theory.

[25] PT/MUL/OAL/C/240.

[26] Alex Soojung-Kim Pang, *Empire and the Sun. Victorian Solar Eclipse Expeditions* (Stanford: Stanford University Press, 2002).

[27] PT/MUL/OAL/C/240, letter 8 February 1918.

[28] David Edgerton, *The Shock of the Old. Technology and Global History since 1900* (Oxford: Oxford University Press, 2007).

[29] Matthew Stanley, "'An Expedition to heal the wounds of war'. The 1919 eclipse and Eddington as Quaker adventurer," *ISIS*, 93 (2003), 57-89; Stanley, *Practical Mystic* (ref.7).

[30] Stanley, *Practical Mystic* (ref. 7), p.104. note 118.

[31] Stanley, "An Expedition" (ref. 29); Stanley, *Practical Mystic* (ref. 7).

[32] Joyce Rodrigues, *Telescópios* (ref. 17), p. 70. The fact that astronomers are presented as practicing Catholics was indicated to me by F. de Almeida.

[33] Marta Macedo, "Standard Cocoa. Transnational networks and techno-scientific regimes in West African Plantations," *Technology and Culture*, 57(3) (2016), 557-58; Miguel Bandeira Jerónimo, *Livros Brancos, Almas Negras: a "missão civilizadora" do colonialismo português, c. 1870-1930*, Tese de Mestrado, 2009; Miguel Bandeira Jerónimo, *The 'civilizing mission' of Portuguese colonialism, 1870-1930* (New York: Palgrave Mcmillan, 2015); Augusto Nascimento, *Poderes e quotidianos nas roças de S. Tomé e Príncipe*, Tese de doutoramento, 2002.

[34] TCL: EDDN A4/2. See also Gisa Weszkalnys, "Príncipe Eclipsed. Commemorating the confirmation of Einstein's Theory of General Relativity," *Anthropology Today* 25(5), 2009, 8-12.

[35] Dyson, Eddington, Davidson, "A determination" (ref. 1), p. 313.

[36] TCL: EDDN A4/2, letter to mother, 11 March 1919.

[37] PT/MUL/OAL/C/240, letter 4 February 1919.

[38] A. C. C. Crommelin, "The eclipse expedition to Sobral", *The Observatory* 42 (1919), 368-71, 368.

[39] TCL: EDDN A4/2, letter to mother, 15 March 1919.

[40] TCL: EDDN A4/2, letter to mother, 15 March 1919.

[41] Crommelin, "Eclipse" (ref. 38), p. 368; TCL: EDDN A4/2, letter to mother, 15 March 1919; PT/MUL/OAL/DD/455, Guestbook; PT/MUL/OAL/C/240, Debt Note from OAL to F.T. Oom.

[42] TCL: EDDN A4/2, letter to mother, 3 September 1912.

[43] Carolino, Simões, "The Eclipse" (ref. 22); Raposo, *Gigante* (ref. 20), chapter 6.

[44] Raposo, *Gigante* (ref. 20), chapter 9.

[45] TCL: EDDN A4/2, letter to mother, 15 March 1919.

[46] TCL: EDDN A4/2, letters to mother, 27 March, 6 and 13 April 1919.

[47] TCL: EDDN A4/2, letter to mother, 27 March 1919.

[48] TCL: EDDN A4/2, letter to mother, 13 April 1919. I was so far unable to find this newspaper.

[49] TCL: EDDN A4/2, letter to mother, 20 April 1919.

[50] TCL: EDDN A4/2, letter to Winnifred, 5 May 1919.

[51] TCL: EDDN A4/2, letter to mother, 20 April 1919.

[52] TCL: EDDN A4/2, letter to Winnifred, 5 May 1919.

[53] TCL: EDDN A4/2, letter to mother, 29 April – 2 May 1919.

[54] TCL: EDDN A4/2, letter to mother, 29 April – 2 May 1919.

[55] TCL: EDDN A4/2, letter to mother, 29 April – 2 May 1919.

[56] TCL: EDDN A4/2, letter to Winnifred, 5 May 1919. He also states that they are distinguished from other Portuguese because "in particular, they do not spit about all the time, and suck toothpicks at meals".

[57] Systematic and exact data on the island's population is not easy to find, so it is necessary to compare sources in order to get a likely estimate. For example, in G. Seibert, "Património edificado de São Tomé e Príncipe. A roça Sundy," in *China e países lusófonos - património construído* (Macau: Instituto Internacional de Macau, 2016), pp. 394-415, it is stated that "in 1908 there were 3,300 servants on Príncipe, the majority of the island's population had fallen to 3,830, of which 150 were white and 350 islanders" (p. 407) (and the population of Príncipe did not exceed 6% of São Tomé). According to *Boletim Geral das Colónias, Vol V-43* (S. Tomé e Príncipe), Portugal, Agência Geral das Colónias, 1929, the population of Príncipe was 5,311 in 1914 and 6,903 in 1921. I thank Duarte Pape for indicating this last source to me.

[58] Jerónimo, The 'civilizing mission' (ref. 33); Weszkalnys, "Principe eclipsed" (ref. 34).

[59] TCL: EDDN A4/2, letter to mother, 29 April – 2 May 1919.

[60] The existence of works at the cable station involving British citizens was mentioned by Oom in correspondence with Eddington.

[61] TCL: EDDN A4/2, letter to mother, 29 April – 2 May 1919.

[62] Eddington does not mention the complex organizational structure of the plantations (roças). Duarte Pape, Rodrigo Rebelo de Andrade, *As roças de S. Tomé e Príncipe* (Lisboa: Tinta da China, 2013).

[63] Dyson, Eddington, Davidson, "A determination" (ref. 1), p.313. The identification of the exact location of the apparatus used by Eddington and Cottingham on roça Sundy resulted from research carried out for the 1919 eclipse centenary commemorations. It was due to joint work with Joana Latas and Duarte Pape. It is illustrated in the catalogue *Einstein, Eddington e o Eclipse. Um encontro improvável, duas expedições memoráveis* (Universidade de Lisboa, 2019), p.51.

[64] PT/MUL/OAL/C/240, letter 4 May 1919.

[65] Approximate time in Greenwich Mean Time, one hour less than local time.

[66] TCL: EDDN A4/2, letter to mother, 21 June – 2 July 1919, italics mine.

[67] *The Observatory* 42 (540) (1919), 256.

[68] Dyson, Eddington, Davidson, "A determination" (ref. 1), p. 316; Eddington, *Space, Time and Gravitation* (ref.9), p. 116.

[69] Dyson, Eddington, Davidson, "A determination" (ref. 1), p. 316.

[70] Dyson, Eddington, Davidson, "A determination" (ref. 1), p. 314.

[71] TCL: EDDN A4/2, letter to mother, 21 June – 2 July, 1919.

[72] Crommelin, “Eclipse” (ref. 38), p. 368.

[73] Crommelin, “Eclipse” (ref. 38), p. 368.

[74] Crommelin, “Eclipse” (ref. 38), p. 368.

[75] Dyson, Eddington, Davidson, “A determination” (ref. 1), p. 297.

[76] According to the correspondence held at the OAL archives, Frederick Brown, a magnetic observer from the Department of Earth Magnetism of the same institution of the American colleagues who settled in Sobral, contacted OAL asking for help to observe in Príncipe. However, eventually he gave up and chose instead to observe in Cameroon.

[77] Morize’s team included Domingos Fernandes Costa and Allyrio Hugueney de Matos, assistants, Lélio Gama, calculator, Luiz Rodrigues, meteorological assistant, Arthur de Castro Almeida, mechanics assistant, Primo Flores, assistant, Theofilo Lee, chemist. L.C.B. Crispino, M.C. de Lima, “A teoria da relatividade de Einstein apresentada para a Amazónia,” *Revista Brasileira do Ensino de Física*, 38(4) (2016), e4203, 1-12, 7.

[78] Crispino, Lima, “Amazonia” (ref. 17); Crispino, Lima, “A teoria da relatividade” (ref. 77); Ildeu Castro Moreira, “A recepção das ideias da relatividade no Brasil,” in Ildeu Castro Moreira, A.A. Passos Videira, eds., *Einstein e o Brasil* (Editora UFRJ, 1995), pp.177-206, p. 179.

[79] Crommelin, “Eclipse” (ref. 38), p. 370.

[80] Dyson, Eddington, Davidson, “A determination” (ref. 1), p. 299.

[81] *The Observatory* 42 (540) (1919), 256.

[82] Since they were created in the Council of Trent, seminaries served to form secular clergy (not religious orders), were linked to dioceses, and were under the responsibility of bishops or archbishops. Sometimes this caused problems and tensions with orders such as the Jesuits, who had their own colleges, patrons and interests.

[83] TCL: EDDN A4/2, letter to mother, 21 June – 2 July 1919.

[84] *The Observatory*, 42 (541) (1919), 261-272, 261-2. Meeting 13 June 1919.

[85] TCL: EDDN A4/2, letter to mother, 21 June – 2 July 1919.

[86] Dyson, Eddington, Davidson, “A determination” (ref. 1), p.314.

[87] Crommelin, “Eclipse” (ref. 38), p. 371; Dyson, Eddington, Davidson, “A determination” (ref. 1), p.302; Crispino, Lima, “A teoria da relatividade” (ref. 77), p.8, p.11.

[88] Dyson, Eddington, Davidson, “A determination” (ref. 1), p.314.

[89] The paper refers that totality occurred from 2h, 13m, 5s to 2h,18m, 7s TMG. Dyson, Eddington, Davidson, “A determination” (ref. 1), p.314.

[90] Eddington, *Space, Time and Gravitation* (ref. 9), p.115.

[91] Dyson, Eddington, Davidson, “A determination” (ref. 1), p.314.

[92] Crommelin, “Eclipse” (ref. 38).

[93] Dyson, Eddington, Davidson, “A determination” (ref.1), p. 299.

[94] There is also an extensive and valuable photographic record produced by the US team recently reviewed in L.C.B. Crispino, M.C. de Lima, “Expedição norte-americana e iconografia inédita de Sobral em 1919,” *Revista Brasileira do Ensino de Física*, 40(1) (2018), e1601, 1-8. Epistemological questions on the various meanings of invisibilities are discussed in Olga Kuchinskaya, “Twice invisible. Formal representations of radiation danger,” *Social Studies of Science*, 43(1) (2012), 78-96;

Olga Kuchinskaya, *The politics of invisibility. Public knowledge about radiation health effects after Chernobyl* (Cambridge, Massachusetts, MIT Press, 2014).

95 I thank Richard Dunn for confirming the reasonableness of these assumptions and for pointing that this tent design, which became standard, was first used on an expedition to observe an eclipse in Japan in 1896.

96 Dyson, "Opportunities" (ref. 11), p.155.

97 Dyson, Eddington, Davidson, "A determination" (ref. 1), p.312.

98 Studies on science diplomacy are blossoming. Among various references, see for example S. Davis Lloyd, Robert G. Patman, eds., *Science Diplomacy. New Day or False Dawn?* (London: World Scientific Publishing Company, 2015). I will address this aspect of British expeditions in a future publication.

99 Dyson, Eddington, Davidson, "A determination" (ref. 1), p.300. In the public announcement at the meeting of 6 November, reported in "Joint eclipse meeting of the Royal Society and the Royal Astronomical Society", *The Observatory* 42 (1919), 389-98, p.390, Dyson refers data conflicting with this one. It is stated that of the 18 plates taken with the astrographic, 15 revealed the required number of stars and only 7 out of 8 plates taken with the other telescope were successful.

100 Dyson, Eddington, Davidson, "A determination" (ref. 1), p.314; "Joint eclipse" (ref. 99), p.392.

101 Albrecht Fölsing, "Confirmation of the deflection of light: 'The suddenly famous Dr. Einstein'," *Albert Einstein* (Penguin, 1997), pp. 433-452.

102 Fölsing, "Confirmation" (ref.101), p.438.

103 Klaus Hentschel, *The Einstein Tower. An intertexture of dynamic construction, relativity theory and astronomy* (Stanford, Stanford University Press, 1997).

104 Fölsing, "Confirmation" (ref. 101), p.439.

105 Fölsing, "Confirmation" (ref. 101), p.440.

106 Fölsing, "Confirmation" (ref. 101), p.440.

107 "Joint eclipse meeting" (ref. 99), p.394. The last sentence is repeated in the newspaper *The Times*, 7 November 1919, p.12.

108 S.G. Brush, "Prediction and theory evaluation: the case of light bending," *Science* 246 (1989), 1124-1129; "Why was relativity accepted?", *Physics in Perspective*, 1 (1999), 184-214; S.G. Brush with Ariel Segal, *Making 20th Century Science: How Theories Became Knowledge* (Oxford, Oxford University Press, 2015), chapter 11. It was not until much later, in 1960, that the verification of the red shift in a gravitational field was corroborated by Robert V. Pound and Glenn A. Rebka, using the 22,6 meter high tower of the Jefferson Physics Laboratory at Harvard University.

109 "Joint eclipse meeting" (ref. 99), p. 394.

110 Matthew Stanley, *Einstein war* (New York, Dutton, 2019).

111 Eddington, *Space, Time and Gravitation* (ref. 9), p. 116.

112 D. Kennefick, "Testing relativity from the 1919 eclipse – a question of bias", *Physics Today*, 62 (2009) 37-42; D. Kennefick, *No shadow of a doubt. The 1919 eclipse that confirmed Einstein's Theory of Relativity* (Princeton, Princetion University Press, 2019).

113 Stars presented streaks that made it very difficult to correctly calculate their displacement relative to the positions on the comparison plates taken two months later with the instrument back in focus. Even before this eclipse there were doubts about the performance of the celostat of the astrographic telescope. See Kennefick, *No shadow of a doubt* (ref. 112), p.201.

[114] Especially from the 1970s onwards, the idea that the 1919 observations were not a decisive experiment became widespread. On the one hand, among physicists, attention was drawn to the lack of rigor of observations. On the other hand, philosophers of science John Earman and Clark Glymour, in an article published in 1980 ("Relativity and eclipses: the British expeditions of 1919 and their predecessors," *Historical Studies in the Physical Sciences*, 11, 49-85) accused Eddington of eliminating data that favoured Newton's theory. This critique was based on a subliminal conception of Eddington as an early advocate of Einstein's theory for reasons not entirely scientific. A re-evaluation of Sobral plates carried out by the Greenwich Observatory in 1979, using a modern machine to measure the positions of stars on the plates, followed by specially designed astrometric data reduction software, yielded a deflection of 1.55" ± 0.34 seconds of arc. It showed that the elimination of plates did not affect results. See summary in Paulo Crawford, Ana Simões, "O eclipse de 29 de Maio de 1919. A.S. Eddington e os astrónomos do Observatório da Tapada," *Gazeta de Física*, 32 (2009), 22-28. All these questions are taken up and clarified, showing the quality of the work of the British astronomers, in Kennefick, *No shadow of a doubt* (ref. 112).

[115] Alfred North Whitehead, *Science and the Modern World* (Cambridge University Press, 1925), p.13.

[116] *The Times*, 7 November 1919, p.12. It was noted that in February Lodge "predicted" that there would be no bending or alternatively if it occurred at all, it should validate Newton. It was also noted that Lodge left the room following the presentation, leaving to the reader the task of causally relating the two statements.

[117] *The Times*, 8 November 1919, p.12.

[118] *The Times*, 7 November 1919, p.12.

[119] *The Times*, 8 November 1919, p.12.

[120] *The Times*, 28 November 1919, p.13.

[121] *The Times*, 28 November 1919, p.14.

[122] Stanley, *Practical Mystic* (ref. 7).