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RESEARCH ARTICLE

The British and Brazilian expeditions and the 1919 total solar eclipse: regimes of labour and degrees of invisibility

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Abstract

In this paper, we dissect how different regimes of labour were crucial to the success of the British and Brazilian expeditions which observed the 1919 total solar eclipse in Príncipe and Sobral. We connect regimes of labour with degrees of invisibility and discuss plausible justifications for various absences/presences in the written records. We discuss reasons for the inclusion of Cottingham, the artisan–technician expert on clockwork mechanisms, into the teams; the entanglements of forced labour with scientific and technical work in Príncipe; and the various regimes of labour in place at Sobral. We argue that the impact of various regimes of labour in Príncipe and Sobral cannot be confined to the provision of infrastructural support, but include critical location choices, the possibility of scientific success during the observations themselves, and the processing of plates following observations.

The observations of the two 1919 British astronomical expeditions which first successfully tested the light-bending prediction put forward by Albert Einstein in the framework of general relativity theory have been the subject of renewed attention by historians of science since the centenary celebrations of this scientific episode. Whether reassessing or extending former arguments or introducing new historical perspectives, international scholarship still resonates with Arthur S. Eddington's original self-fashioned narrative, according to which these expeditions were an exemplar of scientific internationalism and cooperation among scientists across nations, regimes and places, and an important antidote to the deep wounds of the Great War.[1]

However, focusing on the details of the daily workings which made the British expeditions a success shows otherwise. It becomes evident that despite Eddington's plea for scientific internationalism as the episode's cornerstone, the success of the expeditions rested on many other instances of support, not confined to scientific work. Instead they relied on regimes of labour and typologies of actors which were granted varying degrees of (in)visibility in Eddington's publications and recollections, for reasons to be analysed in what follows. The comparison of the two expeditions – the one including the astrophysicist

[1] Daniel Kennefick, *No Shadow of a Doubt*, Princeton, NJ: Princeton University Press, 2020; Mathew Stanley, *Einstein's War*, New York: Dutton, 2019; Stanley, 'An expedition to heal the wounds of war', *Isis* (2003) 94(1), pp. 57–89, and references therein.

Eddington and the expert on clockwork mechanisms Edwin T. Cottingham who observed in the island of Príncipe, then a Portuguese colony and now part of the Republic of São Tomé e Príncipe, and the other including the Greenwich astronomers Andrew C.C. Crommelin and Charles R. Davidson who observed in Brazil's north-eastern city of Sobral – enabled us previously to analyse to several partial or total invisibilities in their publications. These included the omission of Portugal and Portuguese authorities by comparison with those of Brazil, the omission of the identities of the participants who observed totality in Príncipe and probably helped in making the observations (only referenced in private correspondence), or the self-inflicted invisibility of the logistical support that the Portuguese and Brazilian astronomers carried out in preparing the ground for the British expeditions.[2]

Both Eddington and those historians of science who saw through his eyes largely disregarded some of the specificities stemming from the organization of the expeditions during wartime, together with the consequences of observing in localities as different as the colonial/imperial setting of the Sundy plantation in Príncipe or the urban setting of the second city of the state of Ceará in Brazil, then a thriving young nation preparing to celebrate the centenary of its independence from Portugal. As a result, several aspects of the astronomical expeditions which connect them with regimes of labour have not yet been fully appreciated.

In this paper, we join current trends uniting history of science with labour history, put forward by Lissa Roberts, Alexandra Hui, Seth Rockman and others, and dissect how different regimes of labour were crucial to the expeditions' outcome.[3] We do so by connecting regimes of labour with degrees of invisibility, and discuss plausible justifications for various absences/presences in the written records.[4] In the first section, we revisit Steven Shapin's invisible technicians, and argue that while the stringent conditions of the First World War made possible the inclusion of Cottingham, the artisan–technician expert on clockwork mechanisms, in the Príncipe expedition, this direct involvement simultaneously rendered his professional singularity invisible. In the second section, the conditions of forced labour existing in Príncipe are analysed, together with the entanglements of forced labour, including issues of ethnicity, with scientific and technical work.[5] We argue that their impact is not confined to the provision of infrastructural support but also includes the possibility of scientific success during the observations themselves as well as the key task of processing photographic plates following those observations. In the third section, we address how various regimes of labour in place at Sobral impacted on the expedition's output. For Sobral, unlike Príncipe, in addition to the British astronomers, the role of Henrique Morize, the director of the National Observatory of Rio de Janeiro and leader of the Brazilian team, who played a key role in preparing Sobral for the arrival of the British, has to be taken into account. Jointly, they enable us to identify and discuss different regimes of labour, from technical to salaried to hourly paid work, and to highlight how workers of different typologies played a diversity of roles. Notably, these roles were not confined to building material infrastructures. Instead, they included the production of the technical report on which the critical choice of Sobral as observational site was based, as well as active participation in the observation of totality.

[2] Ana Simões and Ana M. Sousa, *Einstein, Eddington and the Eclipse: Travel Impressions*, Cascais: Chili com Carne, 2019; Ana Simões, 'In the shadow of the 1919 total solar eclipse', *Berichte zur Wissenschaftsgeschichte* (2022) 45(4), pp. 581–601; Joel Beckles and Deborah A. Kent, 'Eclipsed by history: underrecognized contributions to early British solar eclipse expeditions', *Notes and Records: The Royal Society Journal of the History of Science*, 2023, pp. 431–52.

[3] Alexandra Hui, Lissa Roberts and Seth Rockman, 'Introduction: launching a labor history of science', *Isis* (2023) 114(4), pp. 817–26; Lissa Roberts, Seth Rockman and Alexandra Hui, 'Historiographies of science and labor: from past perspectives to future possibilities', *History of Science* (2023) 61(4), pp. 448–74.

[4] Olga Kuchinskaya, *The Politics of Invisibility*, Cambridge, MA: MIT Press, 2023.

[5] Steven Shapin, 'The invisible technician', *American Scientist* (1989) 77, pp. 554–63.

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Three astronomers and a clockmaker: Cottingham and technical labour

Cottingham was born in 1869 in Ringstead, in the county of Northamptonshire, near Cambridge. The son of a shoemaker, his early inclination towards clock mechanisms convinced his father to put him under the apprenticeship of the well-established clockmaker Augustus Allen, of Thrapston, a nearby small town.[6] When Allen retired in the 1880s, Cottingham took over his business.[7] His first major work, 'his favourite child', according to Eddington's words on his obituary, was a chiming clock for St James' Church in Thrapston, completed in 1902.[8] The photograph taken to commemorate this moment is his best-known picture. Coincidentally, before dying in 1940, Cottingham's last activity as a clockmaker was to put this clock forward to summertime.[9] But besides his main expertise, he worked throughout his life on a great variety of instruments ranging from sewage-pumping machinery and combustion engines to fountain pens and telegraph and radio equipment.

A tinkerer who introduced himself interchangeably as 'engineer', 'electrical engineer' and 'photo supplier', or more officially as 'specialist for the sale and repair of high precision watches and chronometers' or 'watch, clock and scientific instrument maker', his fame as a clockmaker relates to his astronomical contributions.[10] Cottingham became a member of the RAS in 1905, proposed by the horologist Julien Tripplin. All references to Cottingham on the RAS minutes are concerned with technical aspects, including the requisition of his services to produce, repair, maintain or overhaul clocks or clockwork mechanisms. A significant case in point here was the mending of the institution's Harrison clock, which inaugurated his acknowledgement as a leading expert in this area, and the onset of a profitable and long-lasting relationship with the institution. The Harrison clock was the subject of his article published in the society's *Monthly Notices* in 1909, followed by another in the *Horological Journal* in 1910.[11]

Cottingham's business and skill were aligned with the need for precision instrumentation which arose at the turn of the twentieth century in connection with the growth of radio, telegraph and electrical activities in general. As illustrated by Cottingham's case, 'scientific instrument-makers developed close links with new university departments and laboratories on the one hand, and the new technical industries on the other'.[12] By the end of his career Cottingham's clocks could be found in many observatories around the world.

When the Great War began, Cottingham was already forty-five years old, close to Davidson and Crommelin's ages. As a result, unlike many fellow instrument makers who were either drafted or enrolled in the war effort, he was excluded from conscription. During this period Cottingham executed several maintenance jobs at the observatories of Greenwich and Cambridge, further tightening his connection with the RAS. At the same time, access to this clock collection allowed Cottingham to tinker, and become familiar, with a great variety of precision mechanisms.[13]

One issue especially debated in the RAS at this point was the need to improve the driving mechanisms of coelostats to be used together with telescopes to secure perfect adjustment

[6] Frank Mercer, 'Mr. E.T. Cottingham', *Nature* (1940) 145, p. 653.

[7] '1891 England, Wales & Scotland census', The National Archives, RG 12/1220, p. 18, f. 126.

[8] Arthur S. Eddington, 'Cottingham, Edwin Turner', *Monthly Notices of the Royal Astronomical Society* (1941) 101, p. 131.

[9] Eddington, op. cit. (8), p. 131.

[10] Dennis Jones, 'E.T. Cottingham', *Antiquarian Horology* (1990) 19(6), pp. 593–605.

[11] Edwin T. Cottingham, 'A description of the Society's Harrison Clock, with a brief account of the maker', *Monthly Notices of the Royal Astronomical Society* (1909) 70, pp. 25–8; Jones, op. cit. (10).

[12] Iwan Morus, 'Invisible technicians, instrument-makers and artisans', in Bernard Lightman (ed.), *A Companion to the History of Science*, New York: Wiley and Sons, 2016, pp. 97–110.

[13] Jones, op. cit. (10), pp. 602.

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with the Earth's rotation during solar eclipses. After the failure of the Crimea observations of the 1914 total solar eclipse, and in anticipation of future expeditions, the Joint Permanent Eclipse Committee (JPEC) discussed the need to reconstruct the coelostats. A suggestion was made by the Jesuit astronomer Aloysius Cortie to implement an electrical driving mechanism.[14] The idea was well received, and it was planned that a design by the astronomer–engineer George Gibbs was to be tested.[15] This issue took on a new impetus when it was decided that two British expeditions were to observe the 1919 total solar eclipse. However, even though the inadequacies of the existing mechanisms were not in question, the use of the electrical driving mechanism was dropped: in the interim, Gibbs had been called up and was therefore unavailable. At the 8 November 1918 meeting it was decided instead to draw on Cottingham's indomitable expertise to fine-tune the existing mechanisms. It was also 'provisionally agreed' that Eddington and Cottingham would travel to Príncipe and Davidson and Cortie to Sobral, although war contingencies meant that Cortie would soon be replaced by Crommelin. Similar contingencies affected the composition of the Príncipe team.[16] Eddington's first and second assistants at the Observatory of Cambridge, who could have been considered to join Eddington, had been killed in action. Cottingham's availability and good standing within both the RAS and Cambridge Observatory, the need to secure high performance of the coelostats, and Cottingham's technical involvement in the expedition's preparations made him the obvious choice. His inclusion in the team might well be the reason, as David Kennefick has already noted, for the technical success of the Príncipe expedition: Eddington could devote himself to the telescope and photographic plates, secure in knowing that a technical expert was operating the coelostat.[17] The set-up of the coelostat was certainly Cottingham's purview. During totality, he was responsible for monitoring the driving mechanism as well as for giving the exposures.[18] Surprisingly, in the only extant text by Cottingham regarding the expedition there is no reference to scientific instruments. There is, however, a description of the darkroom set up at the plantation where the observations took place, suggesting that he also assisted in the processing of plates.[19]

While Cottingham's collaboration with Eddington ended with the expedition itself, his involvement in astronomy did not stop with its end. A few months afterwards, the Astronomer Royal, Frank W. Dyson, requested funds for a new standard clock for Greenwich. At the time, the best internationally recognized instrument maker for this level of timekeeping quality was Riefler of Munich. But the admiralty refused to place an order with a German company. As an alternative, Dyson suggested three instrument makers, but recommended Cottingham on the ground that he 'has had more experience than any other British firm with modern clocks of the highest grade'.[20]

As we have noted, Cottingham was the only traveller in the 1919 solar eclipse expeditions who was not an astronomer. The presence of amateur astronomers or even

[14] Joint Permanent Eclipse Commission, minutes, 13 November 1914, RAS Papers, Royal Astronomical Society Library, London.

[15] Joint Permanent Eclipse Commission, minutes, 12 June 1915, RAS Papers, Royal Astronomical Society Library, London.

[16] Joint Permanent Eclipse Commission, minutes, 8 November 1918, RAS Papers, Royal Astronomical Society Library, London.

[17] As Kennefick noted, unlike Sobral in Príncipe there were no issues with the equipment. Kennefick, op. cit. (1), p. 144.

[18] Frank W. Dyson, Arthur S. Eddington and Charles R. Davidson, 'A determination of the deflection of light by the sun's gravitational field, from observations made at the total eclipse of May 29, 1919', *Philosophical Transactions of the Royal Society of London*, 1920, pp. 291–333, 314.

[19] Edwin T. Cottingham, 'Letter dated May 9', *The Observatory*, July 1919, 295–6.

[20] Jones, op. cit. (10), p. 602.

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non-astronomers in British eclipse expeditions was not unusual.[21] In Cottingham's case, the contingencies of war; the close relationship he cultivated with the RAS, Cambridge Observatory and Greenwich Observatory; and his familiarity with the driving mechanism of the sixteen-inch coelestats used in the expeditions were influential for his direct involvement in the expeditions. His technical skills certainly contributed to the (technical) success of the Príncipe team. They built on trust, credibility and personal networking that he had amassed within the RAS. We can argue that if he had remained backstage, he would have likely been invisible to the historian's eye. However, assessing the relative contribution of individual traits and sociopolitical context in the decision to include Cottingham is challenging and dependent on a deeper analysis of his career.

Cottingham's case complexifies Shapin's argument. While the activities of Shapin's invisible technicians were confined to laboratory spaces and their expertise was downgraded vis-à-vis that of the scientific expert, in this case Cottingham's technical expertise was never made invisible by his contemporaries. On the contrary, it was the reason for his inclusion in the eclipse endeavour. However, by highlighting his role in the observational confirmation of light bending, ironically historians have rendered invisible his accomplished career as clockmaker. In what follows, further instances of invisible labour, other than those addressed by Shapin, will be discussed.

Príncipe's colonial context and the pre-eminence of forced labour

Previously, we pointed to the omission of Portugal in most publications related to the expeditions, in the sense that the island of Príncipe was just identified by its geographical location on the west coast of Africa, and not by its colonial status.[22] This omission was possibly meant to obliterate the undesirable political connections associated with the covert practice of slavery (that is, of forced labour) in the peripheral colony of an extended empire. However, there is one exception. It was the report of the meeting of the RAS which took place on 9 March 1917, in which Dyson discussed the possible observational sites for the 1919 eclipse and Príncipe was introduced as 'a well-developed Portuguese island which became celebrated a short time ago owing to the politicians' interest in "slave cocoa"'.[23]

While in this report, addressed only to the readers of the astronomical journal *The Observatory*, there was an explicit reference to the island's colonial status and labour conflicts, this was not the case in the joint paper authored by Dyson, Eddington and Davidson, published in early 1920 in the *Transactions of the Royal Society of London*. This paper, which would have achieved much wider circulation and readership, accounted for the organization of the expeditions, as well as detailing their observations and results. Here, Príncipe was just presented as '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', with no explicit reference to 'slave cocoa'.[24] In the final acknowledgements, there is also a stark contrast between the treatment of the Portuguese and the Brazilian governments. While it credited the support

[21] A good example is John Jepson Atkinson, a wealthy barrister from Cosgrove, who participated in several JPEC expeditions. He went with Dyson to Ovar, Portugal in 1900; Sumatra in 1901; Sfax in 1905, St Germain au Paris in 1912. His last collaboration was in 1912, when he accompanied Eddington and Davidson to Passa-Quatro in Brazil. He was a member of the RAS, but his interest was not scientific, rather in experiencing the spectacularity of eclipses and the adventurous or exotic aspects of expeditions.

[22] Simões and Sousa, op. cit. (2); Gisa Weszkalnys, 'Príncipe eclipsed: commemorating the confirmation of Einstein's theory of general relativity', *Anthropology Today* (2009) 25(5), pp. 8–12.

[23] 'Meeting of the Royal Astronomical Society, Friday, 1917 March 9', *The Observatory* (1917) 40(512), pp. 147–59, 155.

[24] Dyson, Eddington and Davidson, op. cit. (18), p. 312.

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and hospitality of the Brazilian government, presenting Morize as a government representative, and the British astronomers as government guests, there is no reference to the Portuguese government as such. Thanks are addressed to Jerónimo Carneiro, the owner of the Sundy plantation where the observations took place, for his unfailing hospitality, and to his manager, Atalaia, for his 'help and friendship' in such an isolated station.[25] That is, credit is granted to them on an individual basis, not as representatives of colonial institutions.

There is, additionally, no reference to 'slave cocoa' in the official correspondence exchanged between Eddington and the Astronomical Observatory of Lisbon, which provided requested information and logistical support during the preparation and realization of the expeditions. Nor does such a reference appear in the private correspondence detailing his African experience, exchanged with his mother Sarah Ann and sister Winifred Eddington, who both shared with him the premises of the Observatory of Cambridge, informally acting as housekeepers and probably managing his correspondence.[26] Bearing in mind Dyson's discussion as well as the fact that Eddington, like the owners of the chocolate company Cadbury's, was a Quaker, a Protestant denomination known for its pacifist and anti-slavery inclinations, it is likely that he was aware of the decade-old diplomatic clash between Portugal and Britain over the practice of slave labour in the colony. At the time, Príncipe and São Tomé were the major international suppliers of cocoa to Cadbury's, making the chocolate family active players in this conflict.

In our previous papers, we have considered the omission of 'slave cocoa' in both public and private records in the context of Eddington's Quakerism, thus extending Mathew Stanley's analysis of the links between Eddington's religious affiliation, his scientific involvement in the expeditions, and his later actions.[27] Our argument was that being both a Quaker and a scientist observing in a colonial context reinforced his endorsement of the scientific ethos encapsulated in the utopian concept of the Republic of Letters, which distanced science from society and politics. Here, his outspoken defence of scientific cooperation as a form to appease differences and solve conflicts, be they political or diplomatic, was accompanied by the obliteration of the contribution of forced labour to the observations in written records of the expedition.[28] Here we want to explore a correlated strand of reasoning, and discuss how the entanglements between forced labour and other regimes of labour, including scientific and technical work, unfolded during the team's stay at Príncipe, and how these regimes were simultaneously acknowledged and nuanced in the written records.

The absence of an explicit allusion to slave labour in the famous 1920 co-authored paper does not mean that the colonial context was stripped from this publication. It is certainly bypassed in the final acknowledgements, but not in the section on Príncipe. There we learn that the travellers were received upon their arrival on the island by its 'acting administrator', Vasconcelos; by the 'President of the Association of Planters', Carneiro; and by the representative of the 'Sociedade de Agricultura Colonial' (Colonial Agricultural Society) (curiously mentioned just by its Portuguese designation), named Grageira, who 'made all necessary arrangements', including offering the estate of the society for the observations. They add that 'the Portuguese Government dispensed with any customs inspection of the

[25] Dyson, Eddington and Davidson, op. cit. (18), p. 333.

[26] Correspondence involving Eddington, Arquivo Histórico dos Museus da Universidade de Lisboa, Observatório Astronómico de Lisboa, Universidade de Lisboa; Luís Carolino and Ana Simões, 'Behind the scenes: the 1919 total solar eclipse and the invisible labor of the Portuguese and Brazilian observatories', *Centaurus* (2024) 66(1–2), pp. 189–216; Eddington to Sarah Ann Eddington and Winifred Eddington, Eddington Papers, Trinity College Library, Cambridge, EDDN A4/2. 'An important role', *Cambridge Daily News*, 21 April 1954, p. 5.

[27] Stanley, 'An expedition to heal the wounds of war', op. cit. (1).

[28] Ana Simões, 'Astronomical encounters as science diplomacy instances', presentation, ENHCT, Évora, 16 November 2023.

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baggage'.[29] As such the Portuguese government's involvement and Portugal's status as a colonial power are revealed without a shadow of a doubt, even granting that the colonial institution is oddly designated in Portuguese. Furthermore, Grageira, a member of the colonial elite, provided the ice necessary for the on-site development of check-plates before the eclipse, although 'the supply failed after the eclipse'.[30]

The colonial context was also a constant presence in Eddington's correspondence with his mother and sister. To them, he introduced the local elite with many more details than he gave in the 1920 publication: Carneiro was a 'rather young man' who 'owns the largest private plantation' and had only been on the island for two years, the governor is a 'delightful man' who tries to speak in rudimentary English, the *curador* is the man in charge of 'imported labour'.[31] He also listed the judge, harbour master and treasurer, and referred to Atalaia, who became a friend, as a man disillusioned by the fall of the monarchy who sought exile in Príncipe and interacted with Eddington in cursory French.[32] To his sister he went further and confessed that 'the Portuguese here are a very superior type to those we have met before – in particular, they do not spit about all the time, and suck toothpicks at meals'.[33] He also detailed the various leisure activities they were involved in, including picnics, playing tennis, boat rides or listening to music at night on Carneiro's pianola and gramophone at his house in the city of Santo António.[34]

In the 1920 paper, the cursory reference to the director and the deputy director of the Astronomical Observatory of Lisbon, Campos Rodrigues and Frederico Oom, does not reflect the extent of their behind-the-scenes activities. Contacted by Eddington on behalf of the Joint Permanent Eclipse Committee, on 11 November 1918, the day the armistice was signed, the two men were asked for help in the preparation of the expeditions. An exchange of letters ensued, detailing travel routes; support along the way, including the help of colonial authorities and colonial elites on meteorological matters; adequate observational sites; and help during their sojourn at Príncipe. Their involvement was crucial to the success of the expeditions.[35] The troubled political situation in Portugal, the depletion of the Royal Astronomical Observatory due to the war, the unavailability of Portuguese astronomers to accompany the expeditioners, the diplomatic conflict over slave cocoa – all converged to make Portugal and the Portuguese astronomers invisible in the official report, particularly when compared to the presence of Morize and Brazilian authorities.[36]

In the 1920 paper only two other persons are mentioned by name: they are Wright and Lewis of the cable station, who 'kindly assisted us as interpreters when necessary'.[37] In a letter to his mother, Eddington elucidates that they are two black Sierra Leonean British technicians and the sole staff of the local cable station.[38] He had previously mentioned that with him and Cottingham travelled three men who were heading to Cape Verde to work

[29] Dyson, Eddington and Davidson, op. cit. (18), p. 312.

[30] Dyson, Eddington and Davidson, op. cit. (18), p. 316.

[31] Eddington to Sarah Ann Eddington, 19 April 1919, Eddington Papers, Trinity College Library, Cambridge, EDDN A4/2.

[32] Eddington to Sarah Ann Eddington, 29 April 1919, Eddington Papers, Trinity College Library, Cambridge, EDDN A4/2; Eddington to Winifred Eddington, 5 May 1919, Eddington Papers, Trinity College Library, Cambridge, EDDN A4/2.

[33] Eddington to Winifred Eddington, 5 May 1919, Eddington Papers, Trinity College Library, Cambridge, EDDN A4/2.

[34] Eddington to Sarah Ann Eddington, 29 April 1919, Eddington Papers, Trinity College Library, Cambridge, EDDN A4/2.

[35] Carolino and Simões, op. cit. (26).

[36] Simões, op. cit. (2).

[37] Dyson, Eddington and Davidson, op. cit. (18), p. 312; Simões and Carolino, op. cit. (26).

[38] Eddington, op. cit. (34).

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at the cable station at St Vincent, 'the second largest in the world'.[39] In such a way, the submarine cable network launched by the African Direct Telegraph Company integrated in the Eastern Telegraph Company, connecting the British metropolis to India and passing through several strategic localities of the Portuguese empire, including Cape Verde and Príncipe, made itself a presence in Eddington's correspondence.

In a former publication we have suggested that Wright might have played an important role during the observation of totality. Due to his knowledge of English and his technical expertise he would have been able to issue at appropriate times the call regarding plate changes or to take notes of exposure times.[40] This suggestion is supported by cross-checking the 1920 paper, Eddington's recollections in the book *Space, Time and Gravitation* and Eddington's last letter to his mother, dated 21 June 1919. In *Space, Time and Gravitation*, Eddington recalled the emotion of observing totality indirectly by being 'conscious only of the weird half-light of the landscape and the hush of nature, broken by the call of the observers, and the beat of the metronome ticking out the 302 seconds of totality'.[41] In the letter, Eddington provided a meticulous account of the eclipse's totality, the climax of the expedition, making it the sole surviving document in which Eddington names everyone who witnessed totality. Beyond the two travellers, seven colonial staff members, including Wright, were present.[42] The reference to the 'observers' gives room for the possibility that beyond Eddington and Cottingham, Wright might have been actively involved during totality.

While forced labour is never mentioned explicitly in the 1920 paper, a hint is provided by the suggestion that as Carneiro's guests they 'used freely his ample resources of labour and material at Sundy'. Upon the decision to settle at Sundy, native workers transported two tons of equipment roughly one kilometre through the woods, due to damaged rails.[43] Later, they built a stone pedestal for the coelostat. As Eddington noted, native labourers included 'carpenters and mechanics' so that 'it is easy to get any small things required'.[44] Besides these specified tasks, it is likely that many others relating to the material infrastructure for the observations were performed by forced labour. This contrasts to the experience in Greenwich, where the diversion of mechanics and carpenters to the war effort meant that the construction of 'frame huts covered with canvas' and 'steel tubes for the objectives' was left to a civil engineer, Mr Bowen at the Royal Naval College, helped by a joiner. The Greenwich engineer, not the joiner, is identified by name: the Sundy workers are left equally anonymous.[45] However, the extent and profile of forced labour in Príncipe is well known (Figure 1).

By the beginning of the twentieth century, the colonies of São Tomé e Príncipe had become significant global producers of cocoa and coffee. The integration of these colonial spaces in the world economy, through the provision of profitable materials in high demand on the international market, was supported by a monoculture system of exploitation dependent on slave labour and regimes of violence. Most workers in this Portuguese colony were

[39] Eddington to Sarah Ann Eddington, 20 April 1919, Eddington Papers, Trinity College Library, Cambridge, EDDN A4/2.

[40] Simões, op. cit. (2), p. 594; Ana Simões and Ana Sousa, 'Enhancing science education through visual art and complex storytelling using the book *Einstein, Eddington, and the Eclipse. Travel Impressions*', *Science & Education*, at https://doi.org/10.1007/s11191-024-00499-y.

[41] Arthur S. Eddington, *Space, Time and Gravitation: An Outline of the General Relativity Theory*, Cambridge: Cambridge University Press, 1920, p. 115.

[42] Besides Wright, there was Carneiro, the *curador*, the judge, and three doctors. See Arthur Eddington, 'Letter from A.S. Eddington to Sarah Ann Eddington, 21 June 1919', Trinity College Library, Cambridge.

[43] Dyson, Eddington and Davidson, op. cit. (18), p. 313.

[44] Dyson, Eddington and Davidson, op. cit. (18), p. 313; TCL: EDDN A4/2, letter to mother, 29 April.

[45] Dyson, Eddington and Davidson, op. cit. (18), p. 295.

Figure 1. Postcard featuring plantation workers at São Tomé e Príncipe (1928). Courtesy of Fundação Maria Barroso e Mário Soares.

displaced people from Angola and Cape Verde, under a regime of forced labour. Maintaining a workforce in São Tomé e Príncipe was a critical issue for the Portuguese, as these islands had originally been uninhabited.

Although it is sometimes argued that, throughout the second half of the nineteenth century, British direct intervention in Portuguese colonial policy was rare, this was not the case.[46] The slavery issue in particular overshadowed their relations. Due to British pressure, in 1842 Portugal had signed a treaty with Great Britain that was intended to suppress all forms of slave labour in Portugal. However, the abolition of slavery did not occur until 1869, and even then freedmen were required to serve their former masters for approximately ten years in exchange for low, sometimes non-existent, wages. At the end of the nineteenth century, when the cocoa economy was on the rise, large numbers of native workers from Angola, Cape Verde, Mozambique and other Portuguese African colonies migrated to work in the plantations of São Tomé e Príncipe. It is estimated that, between 1885 and 1903, 56,189 workers were Angolan.[47] Despite their being in principle free workers, plantation owners hindered their repatriation upon the end of their contracts. Former slaves and freedmen lived in practice in a situation akin to slavery, without economic autonomy and trapped in old personal relationships.

This situation of covert slave labour attracted public attention in the United Kingdom, the United States and Germany. In this context, William Cadbury, a British entrepreneur who was the most important Príncipe cocoa buyer, following a visit to Lisbon, Angola and São Tomé e Príncipe, published a report denouncing the violent methods used by Portuguese settlers on the islands.[48] Other reports followed, authored by journalists Henry Nevinson, Charles Swan and John Harris. While the Portuguese government refuted British

[46] John Vincent-Smith, *As Relações Políticas Luso-Brasileiras, 1910–1916*, Lisbon, Livros Horizonte, 1975, p. 23.

[47] A.H. de Oliveira Marques, *History of Portugal*, vol. 2, New York: Columbia University Press, 1976, p. 89.

[48] Joseph Burtt and Claude Horton, *Report on the Conditions of Coloured Labour on the Plantations of S. Thomé and Principe: And the Methods of Procuring It in Angola*, Westminster: British & Foreign Anti-Slavery Society, 1907.

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accusations, it simultaneously attempted to correct the situation, encouraging employment contracts more favourable to African workers, ordering inquiries and salary increases. This climaxed in 1909 with a new labour law prohibiting the practice of slave labour. But the tension surrounding virtual slave labour continued throughout the dictatorship (1926–74).[49]

At the time of the expeditions, it is estimated that Príncipe's population totalled around six thousand inhabitants, no more than 3 per cent of whom were Portuguese or European. Therefore most of the population were plantation workers. According to Eddington, Sundy plantation comprised about '600 native labourers'.[50] So probably no more than twenty Portuguese (or Europeans), headed by Carneiro with the help of Atalaia, lived there.

This sheer asymmetry reveals the extent to which the regime of forced labour in a colonial context provided the setting within which the observations at Príncipe were made, and the extent to which eclipsing them from historical narratives erases important dimensions of the astronomical expeditions. In his private correspondence Eddington referred only to the present-day reality of 'imported labour', never to slave or forced labour.[51] This omission resulted from his education in the markedly class-based British society, from behavioural expectations in host–guest relationships, and from the belief in a scientific ethos in which science was wholly separate from political matters, and on which he grounded his future forceful defence of scientific internationalism.

Brazil's national context and the role of various regimes of labour

As mentioned earlier, in the final acknowledgements of the famous 1920 paper, Dyson, Eddington and Davidson thanked the Brazilian government for the hospitality and facilities and for the provision of 'transport, accommodation and labour'.[52]

At the time, Brazil, which was on the eve of celebrating the first centenary of its independence from Portugal (1822), was experiencing an economic boom, under the rule of political oligarchies from the states of São Paulo and Minas Gerais. Following the Republican revolution of 1889, the growing economy of coffee and cattle was complemented by the rise of industry in south-eastern cities. Set against this backdrop of economic growth and political consolidation, Brazil's political and scientific elites framed the total solar eclipse of 29 May 1919 as a defining moment in the nation's emerging modern era.[53]

Beyond the provision of transport and accommodation, readers of the 1920 paper would likely struggle to comprehend the full scope of what labour support entailed. In the oral presentation which announced the results on 6 November 1919, Crommelin, representing the astronomers who travelled to Brazil, provided extra details. In addition to thanking the Brazilian government for their support, along with Morize, Colonel Vicente Saboya de Albuquerque (a federal deputy from Ceará and a Sobral native, who graciously hosted the British team in one of his comfortable houses in Sobral) and Dr Leocádio Araújo (for his translation services and assistance during the observations), Crommelin added an important detail, which is absent from the 1920 paper. He explicitly mentions that Araújo not

[49] Oliveira Marques, op. cit. (47), pp. 87–9; Catherine Higgs, *Chocolate Islands: Cocoa, Slavery, and Colonial Africa*, Athens: Ohio University Press, 2012.

[50] Eddington to Sarah Ann Eddington, 29 April 1919, Eddington Papers, Trinity College Library, Cambridge, EDDN A4/2. Sundy plantation, 'Inquiry for the Curadoria Geral Annual Report', S. Tomé National Historical Archive, 1928.

[51] He mentioned explicitly that about ninety years ago a woman 'slave dealer' lived in the colony. TCL: EDDN A4/2, letter to mother, 29 April.

[52] Dyson, Eddington and Davidson, op. cit. (18), pp. 332–3.

[53] There are several histories of Brazil in English that offer a sound description of these changes, from Burns (1970) to Schwarcz and Starling (2019); E.B. Burns, *A History of Brazil*, New York: Columbia University Press, 1970; L.M. Schwarcz and H.M. Starling, *Brazil: A Biography*, London: Penguin Books, 2019.

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only played a crucial role in timing the eclipse but also offered invaluable support as translator, 'clearly explaining to the workmen our complicated demands'. But who were those workmen? Crommelin did not name any, identifying them simply by their professional categories: 'porters, bricklayers, and carpenters [who] were all freely put at our service'.[54]

In doing so, those subaltern workers went unnoticed by their contemporaries and, moreover, escaped the attention of the historiography that established the standard narrative of this pivotal observation. The origin of this invisibility can be traced to Crommelin's class-based epistemological biases, also shared by Eddington, which prioritized scientific work over manual labour. As a result, he felt compelled to express gratitude to Araújo for his translation services, yet no acknowledgement was extended to those who constructed the sturdy supports for the instruments and the protective structures of the entire equipment. Nevertheless, Crommelin and Eddington were not alone in undervaluing manual labour.

On the other side of the Atlantic, Morize took a similar approach in the conference paper he delivered at the Brazilian Academy of Sciences (Sociedade Brasileira de Ciências) in Rio de Janeiro, on 26 February 1920. Much as his British counterparts had done a few months earlier in London, Morize aimed to present orally the results of the Brazilian expedition that had observed in Sobral. On that occasion, he introduced the three expeditionary teams, specifying their members and research objectives. He summarized Einstein's theory of gravitation and provided some precise details regarding the goals of the British astronomers. Not surprisingly, he focused primarily on the Brazilian team.[55] However, the address, subsequently published in *Revista das Sciencias*, was highly selective. While he explicitly named the members of the Brazilian team, including himself, engineers Domingos Costa and Allyrio de Matos, calculator Lelio Gama, chemist Theofilo Lee, meteorologist Luiz Rodrigues and mechanic Arthur de Castro Almeida, not a single word was devoted to the numerous skilled and unskilled workers involved (Figure 2).

An analysis of the Brazilian case reveals that instances of invisibility stemmed not only from the hierarchical distinction between scientists and technicians but also from the diverse labour regimes in place. While in certain circumstances the salaried workers emerged from obscurity, with their names inscribed in scholarly papers but never as contributors, the hourly paid workers went unnoticed by astronomers, journalists and subsequently historians.

In examining Robert Boyle's case, Shapin highlighted the technicians' double invisibility, encompassing both scientific authorities and historians. This phenomenon was largely attributed to a deliberate decision by Boyle himself, who strategically obscured the technicians' contributions in the public arena.[56] Much later, in the early twentieth century, a similar strategy was employed by Morize. The optimal conditions for observing the total solar eclipse of 1919 in north-eastern Brazil provided Morize with a unique opportunity not only to showcase Brazil as a modern country but also to highlight his own scientific merits on both national and international fronts. To achieve this, Morize focused on leveraging the public dimension of the eclipse.

Morize meticulously prepared the public session at the Brazilian Academy of Sciences, as already noted, extending invitations not only to Rio de Janeiro's scientific elite but also to members of the press. The event took place in a crowded room at the Rio de Janeiro Polytechnic School, centrally located in Rio's downtown. Morize, who in addition to being the director of the National Observatory was a full professor of physics and meteorology

[54] Joseph Thomson, 'Joint eclipse meeting of the Royal Society and the Royal Astronomical Society', *The Observatory* (1919) 42(545), pp. 389–398, 391.

[55] Henrique Morize, 'Resultados obtidos pela comissão brasileira do eclipse de 29 de Maio de 1919', *Revista de Sciencias* (1920) 4(3), pp. 65–81; see António A.P. Videira, 'Henrique Morize e o eclipse solar total de maio de 1919', *Revista Brasileira de Ensino da Física* (2019) 41(1), pp. 1–10.

[56] Shapin, op. cit. (5).

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Figure 2. Participants from the Brazilian, British and American teams in Sobral. Apart from the main group on the right is the carpenter Primo Flores. Courtesy of National Observatory.

at the polytechnic, captivated the audience, earning strong applause upon its conclusion, as reported by the Rio de Janeiro newspaper *Correio da Manhã*.[57] To ensure that journalists could effectively convey the scientific intricacies of an eclipse to their readers, Morize gave them the text of his conference paper. This thoughtful action allowed journalists to select and present the excerpts they deemed most suitable for their audience. Consequently, the following day's edition of *Correio da Manhã* (27 February 1920) provided the Brazilian public with insights into the nature of a total solar eclipse, the scientific objectives associated with eclipse observations, and details about the teams that travelled to Sobral and their respective aims.

In his interactions with the press, Morize skilfully cultivated the image of a scientist – wise, approachable and unpretentious – directing his enthusiasm toward promoting scientific awareness among the public.[58] However, there was little space for acknowledgement of his collaborators, as Morize consistently centred attention on himself. For instance, in dealings with the *Correio da Manhã* newspaper, Morize often circulated his publications not only to control the information shared with journalists about the scientific content in question but also to project an image of profound knowledge.

In the process of securing his scientific persona and visibility in the public arena, Morize also managed to render technicians invisible by excluding them from authorship over scientific work. Morize's conference paper published in *Revista das Sciencias* offers a case in point. As gleaned from this paper, the observation of the eclipse emerged as a collaborative

[57] 'Ainda o Eclipse Solar de 1918 [*sic* – 1919]: O director do Observatório Nacional fala sobre as conclusões da comissão brasileira', *Correio da Manhã* (Rio de Janeiro), 27 February 1920, p. 1.

[58] See, for example, *A Ordem*, Sobral – CE, 21 March 1919, p. 1.

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undertaking from its inception. Nevertheless, when publishing the results of the observations, Morize retained sole authorship of the article. He finished it by briefly thanking his colleagues and collaborators for their commitment to making such a 'hard task' a success.[59] No further thanks were given to his team members who made the observations possible.

Other technicians crucial to the success of the entire eclipse mission were subsequently overlooked in both written and oral reports. One such striking case was Benjamin de Oliveira, who played a pivotal role in selecting Sobral as the ideal location to observe the eclipse. In 1917, when Morize began organizing the reception that would be given to foreign travellers, he explored the possibility of observing the eclipse in the Caxias and Teresina regions, situated on the border of Maranhão and Piauí states, west of Ceará, in addition to Sobral.[60] Morize decided to contact Oliveira, a telegraph engineer with prior experience at the Astronomical Observatory and extensive knowledge of the topography and infrastructural conditions in those remote areas of north-eastern Brazil. Upon receiving a comprehensive report from Oliveira, Morize opted for Sobral due to accessibility, and suitable conveniences for hosting Brazilian and foreign observers.[61] With this information at his disposal, Morize authored a three-page account in French titled *Informations sur la zone brésilienne de l'éclipse totale du 28/29 mai 1919* in early 1918. He dispatched this account to several prominent astronomers, including Crommelin, who was then the secretary of the RAS. However, in this account Morize made no reference to the efforts of Oliveira, totally eclipsing his critical role.[62]

Oliveira shared the same professional standing as most technicians within the Brazilian team. Like engineers Costa and Matos, chemist Lee, meteorologist Rodrigues and possibly the calculator Gama, Oliveira possessed university training and was likely a civil servant. Given this shared professional background, one may ponder whether the omission of Oliveira from Morize's accounts was a purposeful element of Morize's strategy to establish himself as the exclusive authority responsible for the pivotal decisions leading to the successful observation of the total solar eclipse in Brazil. Unlike all other members of the Brazilian team, Oliveira lacked a professional affiliation with the National Observatory and had not been recruited from other public institutions, in contrast to Lee, for example, who was affiliated with the Geological Service. Consequently, from Morize's perspective, there might have been no imperative to mention Oliveira in any official report or scholarly article.[63]

In addition to the technicians, the work of the teams observing at Sobral depended on the contributions of workers who went largely unnoticed in subsequent reports. These overlooked individuals comprised porters, bricklayers and carpenters, as referenced by Crommelin in his report. Despite lacking formal education, they played a crucial role in the success of eclipse observations. Probably unaware of the challenges involved in scientific observations, they skilfully constructed the foundational structures for the instruments and their protective set-ups and provided 'earthen-ware water coolers' (typical regional clay pots) necessary for effectively lowering the temperature of the water and securing the development of check-plates before the eclipse.[64]

In contrast to the forced labour prevalent in Príncipe, the invisible workforce in Brazil were employed on an hourly wage system. In correspondence with higher authorities of the

[59] Morize, op. cit. (55), p. 81. He was the engineer Eugénio Hime.

[60] Morize to the chief of the Secção Meteorológica [letter] (7 July 1917), Observatório Nacional (ON) Historical Archive.

[61] *Apontamentos sobre a zona do eclipse* – informações do Dr Benjamin de Oliveira [report undated], ON Historical Archive.

[62] ON Historical Archive.

[63] Morize to the ministry of Agriculture, Industry and Commerce [letters] (8 April 1919), ON Historical Archive.

[64] Dyson, Eddington and Davidson, op. cit. (18), pp. 298–9.

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Brazilian government, Morize referred to them as the 'subaltern staff', a category encompassing carpenters, guards and servants whom he needed to hire in Sobral.[65] These individuals were likely selected from the poor population of the city, a group markedly affected by the protracted drought in north-eastern Brazil. This climatic adversity prompted significant migration from the hinterlands, or *sertões*, to the principal urban centres of the north-eastern states. Morize indirectly acknowledged this struggling population in a private letter addressed to the chief editor of the *A Tribuna* newspaper. In this communication, he shared that after the eclipse, a group of women who regularly sought charity from Morize's family came to express gratitude for his decision to help them.[66]

Unlike the technicians affiliated with the National Observatory staff, whose names are mentioned but not their work, and similar to the case of Oliveira, whose work and name were erased by Morize, these impoverished labourers received no mention whatsoever in the public domain. Even in private correspondence, they were not individually identified but were only referred to as a social category – the indigent, unskilled workers enlisted to facilitate the essential tasks of the astronomers. This observation underscores that instances of invisibility were not solely a product of the hierarchical differentiation between scientists and technicians but were also intricately linked to the different labour regimes involved in the scientific enterprise.

Concluding remarks

In this paper, the specificities of the various dimensions of labour involved in the 1919 British and Brazilian expeditions have been scrutinized to demonstrate the extent to which scientific work is always supported by other forms of labour that are usually taken as subordinate, less relevant or even irrelevant to the success of scientific endeavours. However, 'invisibility' is not something that emerges from Shapin's original dichotomy between scientists and technicians, but instead needs to be treated as a more nuanced category, which is negotiated through the various gradations and status of regimes of labour.

So, for example, while Shapin's argument is corroborated by Morize's strategy of eclipsing his technical collaborators, Cottingham's case contradicts it. Cottingham's recognition as a clockmaker was co-constructed with his membership of the RAS. His technical expertise was highly visible and respected by astronomers. But his participation in the British teams who observed what was to become one of the most famous eclipses, and one of the high points in the history of physics, had an unexpected side effect. Cottingham's portrayal produced the flattening of his long career as a scientific instrument maker.[67] It is time to get him back into the limelight for all the technical dimensions in which he excelled.

Besides scientists and technicians, other labourers – including the salaried or hourly paid, and even the forced – were involved in studying the eclipse. The specificities of the different contexts in which the expeditions unfolded, from the impact of global war to the differences between the imperial and colonial approaches of Britain and Portugal, as well as the experiences of a young nation emerging from centuries of colonial domination, must be taken into account in examining this episode. The extant written and oral records reveal varying kinds of invisibility in considering the various roles and entanglements played by different social groups. Even within each professional category, and most especially within the broad spectrum of technicians, different degrees of invisibility reflected once again a

[65] Morize to the ministry of Agriculture, Industry and Commerce [letters] (8 April 1919), ON Historical Archive.

[66] Morize to the redactor of *A Tribuna* [letter] (25 July 1919), Museu de Astronomia e Ciências Afins Historical Archive.

[67] Kennefick, op. cit. (1); Stanley, *Einstein's War*, op. cit. (1); Simões and Sousa, op. cit. (2).

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hierarchy of regimes of labour, within which asymmetries of agency were tied to asymmetries of power. This is not to say that invisibilities and regimes of labour go always hand in hand, but it is certainly the case that they are intimately connected.

Publications and correspondence make it clear that the observation of totality and revelation of check-plates were dependent on on-site technical work and materials provided by colonial authorities and technicians, associated with the Portuguese and the British empires in the Príncipe case, or provided by the national elite, state authorities and technicians or even native workers in Sobral. Under different regimes of labour and violence, in both locations native workers secured the material infrastructural support, including transport of materials, mounting tents, building pedestals, producing ice or providing clay pots. While they all went unnamed, their participation was essential, even if the astronomers, and specifically Eddington, opted to omit the practice of forced labour by the Portuguese colonial power in their written accounts. In any case, central aspects of astronomical work and empire were irretrievably entangled.

While many participants remained nameless, others were not stripped of their identity. Most frequently, these were technicians such as Lewis and Wright in Príncipe or Araújo in Sobral, members of the colonial and national elites – although not Oliveira, despite the fact that his work was decisive for the choice of Sobral as observational site. The astronomers' choice to selectively identify some workers to the exclusion of others was grounded on engrained epistemological biases, ranking scientific work over manual labour. Within the ample category of manual labour, a sharp distinction was established between technicians and skilled and unskilled workers under different regimes of labour – salaried, hourly paid or forced. Scientific and social prejudices account for various degrees of invisibility. That they still pervade many historical works invites us to reflect on our responsibility to the past, and on the urgency to articulate seriously a labour history of science.

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