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ASTRONOMICAL FIELDWORK AND THE SPACES OF RELATIVITY

The Historical Geographies of the 1919 British Eclipse
Expeditions to Príncipe and Brazil

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ABSTRACT: This paper looks at the British eclipse expeditions to Brazil and Príncipe of May 1919, which were undertaken to find proof of Einstein's general theory of relativity by measuring the deflection of starlight at a solar eclipse. Much has been written on the mathematical implications of the results of these eclipse expeditions and the motives of the astronomers involved, but less attention has been paid to the expeditions themselves. In analyzing the specific geographies of these expeditions, this paper will demonstrate that they were shaped by a multitude of factors, including networks of commerce and political relations in a world of growing postwar international cooperation and colonial legacies, while also affirming the importance of the expedition as a tool of research for astrophysical and astronomical science at this time. Analyzing the roles of colonial administrators and unnamed assistants that took part in the expedition process along with the spaces within which they worked provides a critical geographical view of these expeditions and their significance as an episode of early twentieth-century science.

KEYWORDS: *spatiality of science, eclipse expeditions, Príncipe, Brazil, Eddington*

INTRODUCTION

The summer of 2019 will mark one hundred years since the expeditions of four British astronomers to Brazil and the West African island of Príncipe. These expeditions—to view the total solar eclipse of May 29, 1919—have special significance in the history of science for their role in confirming Albert Einstein's groundbreaking theory of relativity. In the midst of the First World War, ideas about gravity's effect on light had been communicated across tense political borders from Germany to Britain, where they struck a chord with leading astronomers. Relativity was a revolution in the scientific world and represented the most

significant change in the way the laws of the universe were understood since Isaac Newton's discoveries in the seventeenth century. The theory proposed that rays of light were subject to gravitational pull. The position of certain stars in the sky changing due to their light being bent by the gravitational pull of the sun was the most straightforward example of this process at work. Such was the complexity of this theory, the only feasible way of proving it correct would be to measure the deflection of starlight by the sun at a total solar eclipse, the path of which would take the viewing parties thousands of miles from home to two separate locations in the tropics. With the sun's intense light blocked by the moon, astronomers would be able to plot the position of several stars in the sky and compare these with their corresponding positions when the sun did not occupy that position in space. The Joint Permanent Eclipse Committee (JPEC) of the Royal Astronomical Society (RAS) and the Royal Society made plans to send four astronomers to view the eclipse—two to Brazil and two to the island of Príncipe—in the hope that Einstein's theory could be successfully tested.

These expeditions were novel in that they were the first to successfully produce results from observing the deflection of starlight at a total eclipse, and they remain perhaps the most famous example of expeditionary astronomy in the early twentieth century. The success of these expeditions, which lasted several months over the spring and summer of 1919, was contingent on numerous different actors who contributed to their planning and execution, as well as the networks of transport through which the astronomers moved. Also critical to their success were the sites at which this science was practiced, with the geographical characteristics of the observation stations crucial to how the astronomers viewed the eclipse and recorded results. In identifying the mobilities of the astronomers, their decisions on where to view the eclipse, and the spaces at which they made observations, this paper will ask a range of questions of these expeditions. How were the planning processes of the expeditions contingent on networks of geographical and astronomical knowledge? What methods of transport did the astronomers employ, and how were their mobilities shaped by the geographies of existing travel networks? How did the spatial characteristics of the spaces the astronomers used for observations matter, and were these affected by the legacies of imperialism? This paper will address these questions from a historical geographical perspective that will place a localized study of

astronomical fieldwork within broader economic, political, and social processes and structures.

Situating Science

Using a spatial perspective that acknowledges the influence of geographical factors in tying together the actors, networks, and sites critical to the conduct of these expeditions, this paper will show how an understanding of the geographies of these expeditions is key to understanding their success. Showing that fieldwork was crucial to making the necessary observations will also underscore that expeditionary astronomy remained an important method of research in the early twentieth century. Recent literature makes it clear that place has a significant influence on the outcome of scientific work, and focusing on this can help us locate expeditionary astronomy within historiographical approaches concerning the spatiality of science.¹ Such approaches are now frequent in studies of the history of science, with Nielsen, Harbsmeier, and Ries noting how recent scholarship in this field has “increasingly subjected the many forms of scientific practice to studies of the social, cultural and material conditions under which they occur.”² This “geographical turn” has highlighted how across various disciplines, geographical factors and the spaces where science is conducted lend authority to and enable or constrain various types of scientific practice.³ The value of geographical analysis in history of science studies has prompted Simon Naylor to conclude, therefore, that “historical geography can be a rich resource for all those interested in producing nuanced accounts of science’s history.”⁴

Analyzing these expeditions through a lens of historical geography creates room for identifying how astronomical fieldwork in the early twentieth century could be contingent on a range of different geographical factors. Such an approach is missing from existing accounts of these expeditions, which range in their focus from scrutinizing the scientific results to an appreciation of the expeditions’ cultural legacies. A biographical angle is offered by Matthew Stanley, for example, who has written extensively on the personal motivations of Sir Arthur Eddington, leader of the expeditions, in carrying out this work.⁵ Adding a spatial analysis to biographical accounts such as these has become a fertile ground for research in historical geography as the lives of influential figures, according to Stephen Daniels and Catherine Nash, are becom-

ing increasingly charted “in terms of movement and settlement.”⁶ The mathematical basis of the observations and their results has been dealt with by writers such as Donald Moyer and Earman and Glymour, while cultural legacies of the work in Portugal have been explored by Mota, Crawford, and Simoes.⁷ These accounts all offer different interpretations of the expeditions, yet none delves into how the conduct of this work was influenced geographically. A geographical approach will highlight how the spatial characteristics of sites including plantations and commercial steamers, and the networks present at each of the locations the astronomers found themselves throughout the expeditions, were integral to their success. These networks allowed for the circulation of astronomical knowledge (including where best to view the eclipse) and geographical knowledge of the sites from which observations could be made. This comprised information regarding the geographical characteristics of potential viewing areas, the shipping companies that offered routes to these places, and other transport information needed to access viewing sites. Highlighting these networks offers an interconnected view of these expeditions, something historians of science are growing increasingly concerned with promoting in studies of scientific practice.⁸

Fieldwork and Astronomy

Thinking about the spatial characteristics of the places featured during these expeditions is critical given that they involved working outside of the more controlled boundaries of the observatory, with fieldwork necessary to achieve the intended results. Scholarship in historical geography over the last two decades has sought to elucidate the significance of scientific practice in the field, exposing the various practices, problems, and processes that arose during the conduct of field science throughout the eighteenth and nineteenth centuries.⁹ Expeditions were integral to this field science. These were thoroughly planned, often state-funded ventures commonly undertaken by a group of explorers, scientists, or military personnel, to all corners of the globe where they could interact with native peoples, chart new lands, and conduct the science of empire. Throughout the nineteenth century, scientific expeditions directly benefited from improving technologies of transport, instrumentation, and resources previously unavailable to European explorers. An established body of work exists on how knowledge was made and communi-

cated through the networks of colonialism present across the world in the eighteenth, nineteenth, and early twentieth centuries, with geography and expeditions emerging within this work as important tools for the creation of empire.¹⁰ Recently, the growing importance of studying interactions between European expeditions and native communities in colonized regions has been argued for by authors such as Felix Driver and Lowri Jones, who emphasize the contributions of intermediaries and local assistance to the production of knowledge throughout the imperial world.¹¹ Indeed, the new possibilities in the fields of botany, geology, and biology that were opened up by colonial expansion across the globe facilitated expeditions and an application of science in the field.¹² Fieldwork has therefore become an important line of inquiry for historians of science, who, as Henrika Kuklick and Robert Kohler put it, “should not lose sight of the features of the field sciences that make their history different from that of other varieties of cultural history.”¹³

This analysis of expeditionary science in the late nineteenth century has extended to astronomy, too, with numerous authors detailing the conduct of expeditionary astronomy in this period. The latter half of the nineteenth century saw an explosion in the number of astronomical expeditions organized to points all over the world to view special celestial phenomena, including total solar eclipses or planetary transits across the sun. This exploratory activity by astronomers has been the focus of many historians of astronomy, and historians of science more generally, who have looked to place such scientific endeavor within the wider cultural frameworks of Victorian science. Studies of the scientific culture of eclipse science and expeditions in the latter half of the nineteenth century, including work by Alex Pang, have demonstrated how the changing technologies of astronomy in this period inspired new inquiry and led to the organization of dedicated eclipse-chasing groups within professional astronomical institutions.¹⁴ Pang’s work, which focuses predominantly on the second half of the nineteenth century, reveals the complex links between science, society, and technology in the work of British eclipse chasers, as well as the various networks through which such knowledge moved and was debated. The Transits of Venus in 1874 and 1882 have been the focus of authors like Jessica Ratcliff, who explores some of the cultural encounters that emerged out of the expeditions that astronomers organized to view them. She also identifies how astronomical science was produced and

circulated through imperial networks at this time, while framing this expeditionary work within the national fervor generated by events of “big science” in this period.¹⁵ A smaller-scale approach is offered by Michael Chauvin, who looks at one specific transit expedition through an investigation of research by British astronomers in Hawaii in 1874. As well as attending to the scientific processes involved in making the correct observations, he explores how such astronomical science was connected to determining longitudinal values in the Pacific, and how interactions with native islanders influenced the work of astronomers in many different ways.¹⁶ The influence of indigenous peoples on eclipse expeditions is also studied by David Aubin, who has written on the politics of eclipse viewing in Thailand in 1868. Aubin details how nation building, the establishment of local scientific traditions, and political power can all be intimately tied in with the study of solar eclipses.¹⁷ These accounts reconstruct the lives of astronomers in the field and help us understand the conduct of these expeditions within the scientific, cultural, and social networks that shaped them. They do not, however, explicitly engage with the influence of geographical factors on these expeditions and networks. In Chauvin’s case, for example, the transitory phases of the expedition are overlooked, with no more than a summary of the route traveled by the astronomers and a mention of the names of the ports their ships sailed from. Similarly, the sites at which the astronomers made their observations are often taken for granted by historians. Information on the areas the astronomers were based is often descriptive in nature with little analysis of why these spaces were so suitable for the work, effectively separating the astronomical work from the local geographical conditions in which it took place. Drawing on the examples featured in this work that shed light on expeditionary conduct, this paper will add a new perspective by showing that the geographical conditions of the expedition process, from the weeks spent at sea to the unfamiliar environments in which astronomers made observations, were significant factors in shaping this conduct and the science it produced.

Expeditionary Science in the Early Twentieth Century

While expeditions had been an integral facet of the scientific program throughout the nineteenth century, it has been noted that the early

twentieth century saw a decline in the number of imperially motivated expeditions across the world. The turn of the century was referred to as the end of the age of exploration, with Halford Mackinder stating to the Royal Geographical Society in 1887 that “we are now near the end of the roll of great discoveries.”¹⁸ Recent work, however, has sought to dispel this notion. Simon Naylor and James Ryan have suggested, for example, that exploratory practices continued into the twentieth century, with scientific expeditions taking advantage of new technologies and links between people in an increasingly connected world.¹⁹

Where expeditionary science of the Victorian era had focused on the accumulation and circulation of imperial possessions, similar endeavors of the early twentieth century were more concerned with expanding the boundaries of knowledge and pursuing the unknown. Perhaps the best-known example of this science in the early twentieth century is polar exploration, including the infamous expedition of R. F. Scott to the South Pole in 1911. The expeditions to the Antarctic garnered considerable attention for the tragic end to which several of the explorers came. The daring exploits of the men involved were communicated to the public via photography and personal accounts, and recent literature focusing on these expeditions has drawn out the impacts of these representations.²⁰ Across other sciences, expeditionary work to find the South Magnetic Pole and the research of botanists in Southeast Asia further exemplifies how scientific work in this period was very much still concerned with exploration and the benefits of the expedition and its associated technologies as a tool of research.²¹ Like the exploration of the Antarctic and the charting of the last uncharted territories, astronomical science of the early twentieth century was pushing the boundaries of existing knowledge. In this period, solar eclipses continued to be the prime interest of the astronomer in the field, but the scientific lines of inquiry associated with them were changing from making observations of the sun’s corona to testing the novel theories of physicists such as Einstein. Rather than being undertaken for any explicit imperial aim, expeditions to test such theories were part of the pursuit of an expanded knowledge of the universe. However, as this paper will draw out, the legacies of empire could still be felt in these spaces of science.

Aside from the previously mentioned material on the 1919 expeditions, literature on astronomical expeditions in the early twentieth century is sparse. The few accounts of expeditionary astronomy in the

early twentieth century that exist concentrate on the changing relationship between amateur and professional astronomers and the growing presence of women in astronomical work.²² Pang's work on Elizabeth Campbell and the Crocker-Lick Observatory eclipse expeditions offers a unique study of the roles played by women in the field, how such work could be gendered, and the emotional experiences associated with eclipse expeditions. He also offers a sense of the conduct of such expeditions at the beginning of the twentieth century, and this paper will take a similar approach in detailing the conduct of the British expeditions in 1919. As Pang notes, while the instrumentation and experimenting of science is important, the administration, management, and technical work should not be overlooked: these are crucial facets of expedition work, "for much work is required to get a party into the field and to reduce and publish results after it has returned."²³ Studying the conduct of these expeditions more closely, alongside the spaces and mobilities woven through them, will show how geographical factors were of central importance to the work of expeditionary astronomy in the early twentieth century. This paper will argue that geographical contingencies should be an important consideration for those attempting to tie together the legacies of imperialism, mobilities, and the networks of scientific communication in such work.

This paper draws from archival information held at the Royal Astronomical Society in London and at the Cambridge University Library, two of the main repositories of archival material on astronomical science in Britain today. It includes the personal letters of the English astronomers who organized the expeditions, Sir Arthur Eddington (who led the expedition to Príncipe) and Astronomer Royal Sir Frank Dyson. The minute books of the JPEC are also used, alongside articles published in associated contemporary journals and publications such as the *Monthly Notices of the Royal Astronomical Society* and *The Observatory*. Eddington's letters to his mother and sister provide insights into the daily processes of the expeditions while he was traveling and relay some more personal reflections. Information such as this is often absent from more official accounts of the expeditions published by the RAS and assists in bringing to light some of the finer details of the expeditionary conduct.

Taking a chronological and geographical approach to analyzing these expeditions, this paper will be split up into four main sections. It will

first detail the planning of the expeditions at the RAS, and the networks of astronomical knowledge that helped the astronomers decide that Príncipe and Brazil were the best locations to view the eclipse. Second, it will look more closely at the spaces of the two ships the astronomers used in reaching these destinations, the *Anselm* and the *Portugal*, investigating how these commercial ships acted as part of a network of travel that differed from certain methods of travel on previous astronomical expeditions. Third, by exploring the geographies of the two viewing sites at a plantation on Príncipe and at a racecourse in Sobral in northeastern Brazil, the paper will demonstrate how geographical contingencies including the imperial legacies of the cocoa trade in West Africa and the amenities of Sobral could impact the science undertaken at these places. Finally, the conclusion will draw together the main findings of this paper, tying the two expeditions together and summarizing the importance of thinking about the spatial characteristics of their conduct throughout the expeditionary process.

THE CONTEXT AND PLANNING OF THE EXPEDITIONS

Einstein's ideas of relativity had come to England via Dutch physicist Professor Willem de Sitter during the First World War and the embargo on German science.²⁴ Astronomer Royal Sir Frank Dyson and prominent Cambridge mathematician and astronomer Arthur Eddington saw the upcoming eclipse of 1919 as a prime opportunity to test the German's theory. As the bright Hyades cluster of stars would be present in the eclipse field, this was an extremely favorable occasion to measure the deflection of starlight. All other eclipse activities, including spectroscopic observations of the sun's corona—an analysis of the chemical composition of the sun through measuring the wavelength of light—which had come to characterize the majority of work undertaken during solar eclipse study, would be postponed until later eclipses. The British expeditions were not alone in their ambition of measuring the deflection of starlight at an eclipse. Several expeditions led by astronomers across the globe had made failed attempts to make observations in the years preceding 1919.²⁵ Eddington was also a pacifist and a Quaker. As Matthew Stanley argues, this meant that Eddington saw the opportunity to verify Einstein's theory as a "religious calling" and potentially a route toward the healing of international relations

via the promotion of scientific cooperation between nations.²⁶ His conscientious objection to the war caused some logistical difficulty, however, with Dyson using his connections to the admiralty to excuse Eddington from conscripted service, which would have seen the expeditions jeopardized from the beginning.²⁷

The geographical decisions and influences present during these expeditions are evident from the early stages of their planning. Eddington and his colleagues could call upon a wealth of experience in planning eclipse expeditions developed over previous decades by the RAS, and the novel observations required to test Einstein's theory meant that such knowledge was again essential to their preparations. Clear viewing conditions were always sought after for eclipse viewing, and as the subject of the astronomers' study was the stars that would become visible due to the sudden darkness brought about by the eclipsed sun, their faint light would require a perfectly clear and still sky to be seen properly. The path of totality across the face of the earth varied from eclipse to eclipse and could be calculated years in advance via a geometrical analysis of the movement of the moon and the earth. This varied path meant that commonly, the only option for study was to leave the established centers of astronomical inquiry and travel to the perfect location for viewing. The path of the eclipse in 1919 ran through northern Brazil and across the Atlantic Ocean before crossing the western coast of Africa and the islands of Cape Palmas and Príncipe and ending near Lake Tanganyika. Close connections to the Royal Geographical Society (RGS) and other astronomical centers were important for planning these expeditions. Mr. Arthur Hinks, the secretary of the RGS who is best known for determining the distance from the earth to the sun, made an inquiry as to the most suitable location and weather conditions at each potential site.²⁸ Choosing an appropriate site from which to make the observations was far from an easy task, demonstrating that astronomical science was closely intertwined with geographical knowledge. The humidity of the air, convection currents, and temperature gradients were all part of the equation, meaning that it was not just ease of access to a location within the band of totality that influenced the expedition planners. Rather, an assessment of the local geographical features was also important. At the Kashmir Temporary Observatory in India, English astronomer John Evershed wrote to the members of the RAS in May 1917 to express his concern that a site near Lake Tanganyika would see the eclipse too

low in the sky to make appropriate observations. Drawing on his own experiences in the valleys of Kashmir, where the lakelike conditions of the local rice fields offered superior solar definition to the surrounding hills, Evershed instead suggested the organizers should “make great efforts to secure an oceanic island site,” where atmospheric conditions would likely be similar. He pointed out that two such islands lay in the path of the eclipse in the Gulf of Guinea, the island of Príncipe and Corisco Island, near Libreville in Gabon. Underlining the importance of the work to be undertaken on these expeditions, Evershed even suggested preliminary expeditions to these islands in 1918 should they be chosen, to test the suitability of climatic conditions.²⁹

Sobral, a town in northeastern Brazil, was selected after the members of the RAS had received a circular from Dr. Henry Morize, the director of the observatory in Rio de Janeiro. This circular provided “copious” information on meteorological conditions, points of access, and other positive attributes of the location, and convinced the British astronomers that it offered the best choice for a viewing station in Brazil.³⁰ The JPEC met on November 10, 1917, and decided that two expeditions should take place to view the eclipse of May 1919—one to Sobral and the other to the island of Príncipe—to minimize the chance that inclement weather would spoil observations. For funding, applications were made to the British Government Grant Committee in the order of £100 for instruments and £1,000 for the costs of the expeditions themselves.

An eclipse subcommittee met six times in total before the expeditions were due to begin in early 1919 with the meetings mostly involving confirming the logistical details of travel and which instruments were most suitable for the task at hand. Eddington and his assistant, Mr. Edwin Cottingham, would travel to Príncipe, while Dr. Andrew Crommelin of the Royal Observatory Greenwich and his assistant, Mr. Charles Davidson, would go to Brazil. The selection of Príncipe goes somewhat against the grain of regular selection of sites for eclipse observation. As Pang has noted, eclipse-viewing parties commonly made sure to pick a site that was easily accessible by rail, due to the “close links between railroads, resources, and safety.”³¹ There was no such developed railway infrastructure on Príncipe, and that it was chosen as a viewing site is testament to its geographical features and the persuasive suggestions of the Portuguese astronomical community, of which more below.

Expeditionary astronomy had been a science of lengthy preparation

for centuries, with the choice of precision instruments and vessels upon which to transport them constituting some of the most important decisions faced by astronomers.³² The four men were to bring the object glass of an astrographic telescope to each location, along with sixteen-inch coelostats (rotating mirrors for the telescopes) and a four-inch telescope used at a previous eclipse in 1914. The minutes of their meetings reveal the various connections that were established before the expeditions got under way, serving the astronomers with travel arrangements, contacts, and means of accommodation and hospitality once they arrived at their destination. Many different points of contact were established, including the Ministry of Shipping; the Brazilian delegation in London; telescope manufacturer Sir Howard Grubb in Dublin, who was able to quote prices for insuring the instruments; the observatory in Lisbon; and even the Portuguese “Provincial” Father Pinto, who contacted his colleagues in Brazil requesting a warm welcome for the astronomers.³³ The expedition planners came to rely on such diverse networks of contacts to formulate their strategies for choosing sites of observation, the methods of travel to get there, and the equipment they used upon arrival. The planning was concentrated through a network of local knowledges, connected at a global scale. Contact with people such as Dr. Morize across the Atlantic Ocean and the staff at the Lisbon observatory demonstrates that these expeditions relied on the circulation of these knowledges, providing them with the information they needed to establish appropriate expedition plans.

TRANSPORT TO THE TROPICS

With their instruments safely on board, the astronomers sailed on the RMS *Anselm* from Liverpool on March 8, 1919. The *Anselm* had been a First World War troopship, and once decommissioned, it became a vessel of the Booth Line, which specialized in transatlantic routes to Brazil.³⁴ Instead of carrying soldiers, most of her passengers were now members of the general public, including holidaymakers and people of business. It was used for several years on the Liverpool-Lisbon-Brazil route, and it was this preexisting trade and commercial travel network of which the astronomers took advantage. For the purposes of these expeditions, it was convenient that the Booth Line offered such a route as it allowed relatively quick and affordable travel to two parts of the

world that were in the path of the eclipse of May that year. While this Booth Line route did not include Príncipe and the Gulf of Guinea, the inclusion of the Portuguese island of Madeira off the northeast coast of Africa as part of the route allowed the men to access further transport to the coast of West Africa.

Existing scholarship discussing the importance of ships for scientific expeditions (including expeditionary astronomy) has tended to focus on the use of military vessels, specifically chartered for use on the scientific expedition they were part of.³⁵ Richard Sorrenson, for example, has argued that James Cook's *Endeavour* represented an essential tool for his expeditions, providing a mobile base from which measurements of climatic conditions and the geography of the antipodean coastlines could be made, while also using astronomical observations to determine longitude.³⁶ Without dedicated military assistance, the British astronomers sailing to Príncipe and Brazil in 1919 instead relied upon the knowledge and skills of navigation possessed by commercial ships and their crew, which were the legacy of imperial shipping routes and connections forged in previous centuries. The expeditions of 1919 highlight how commercial shipping, commonly neglected in studies of how ships have contributed to scientific work, was an integral part of the scientific journey. Commercial shipping was only just reemerging from the turbulence of the war; of the Booth Line's fleet of more than thirty ships, eleven had been requisitioned for war service, of which nine had been sunk. Voyage by sea would have been problematic during wartime, if not impossible, and the effects of the war challenged the traditional means by which astronomers undertook expeditions. The Victorian era had seen astronomers given generous funding and the use of large military vessels to travel across the globe; however, the stress on resources meant travel arrangements in the immediate aftermath of the war were much more frugal. The astronomers had originally intended to request an admiralty ship for their expedition, but the availability of a commercial shipping line that visited both West Africa and Brazil rendered such transport an unnecessary expense. Given that many of Britain's warships had been tied up in combat during the planning stages, this request would most likely have been futile.³⁷ Steamers had been used by astronomers on short expeditions to locations such as Spain in the early years of the twentieth century; however, it was still common for admiralty ships to be employed on some of the longer voyages. When

two British parties went to view an eclipse in Tonga in 1911, for example, the HMS *Encounter* was called upon to achieve safe passage to the Pacific.³⁸ The expeditions of 1919 demonstrate that astronomers were becoming more comfortable with the use of commercial liners for longer voyages, with the improved networks of travel by sea offering quick and safe transport to their destinations. When British astronomers planned to view an eclipse passing over Christmas Island near Indonesia in 1921, they were more than content to rely on steamers for their transport.³⁹

To reach Príncipe from Madeira, Eddington and Cottingham traveled on the *Portugal*, a liner belonging to the Companhia Nacional de Navegação. This shipping company served routes between Portugal and Africa, including some of Portugal's colonies on the continent including Príncipe and Angola. Despite a minor delay prompting Eddington to remark that "one cannot rely on the boat times at all," their time on the *Portugal* passed without incident. On board the two men enjoyed the company of an English-speaking Portuguese army officer, played games with the other passengers, spoke at social functions in the ship's saloon, and indulged in some of the regional cuisine served on board.⁴⁰ While not as luxurious as the *Anselm*, the *Portugal* provided a comfortable travel experience. Both ships were a far cry from the military vessels that provided astronomers with transport in previous decades. The *Anselm* and the *Portugal* do not represent traditional sites of scientific activity in the vein of Cook's *Endeavour*, but instead serve as an example of the social and cultural spaces within which astronomers could move in this period and speak to the importance of commercial shipping networks for this movement. The ships were not the exclusive domain of the astronomers, but they nonetheless offered first-class passage, a relatively quick voyage, and the opportunity to informally discuss and plan arrangements for observations prior to arrival. The resumption of commercial shipping services, including the Booth Line, after the war saw a wide variety of people once more take to the seas to travel. These ships were part of a wider culture of commercial travel by steamship, as from the late nineteenth century onward, they became sites that facilitated the travel of not only tourists but also engineers, missionaries, doctors, and artists. The spaces of these ships encouraged socializing and stimulated intellectual conversation between passengers.⁴¹ Eddington notes how his fellow passengers included people on missionary work and men working at cable stations on some of the smaller islands between Portugal

and Príncipe. Staying in spacious first-class rooms on board, socializing among the other first-class passengers and higher-ranking members of the ship's staff, and taking in the good weather—Eddington remarking that “one could sit out on deck chairs without an overcoat” for the majority of the time on the *Anselm*—the transitory phase of the expeditions appears to have been mostly a time of relaxation.⁴²

These ships can be understood as instruments used in transporting the astronomers to their desired locations. They were the physical manifestations of the travel networks on which the astronomers relied to reach their destinations with their fragile and expensive instruments intact. While not quite the “inked needle of an instrument of enormous proportions”—as Bruno Latour describes the scientific vessel of exploration—these ships and the routes they followed had similar functions in the accumulation and circulation of knowledge as the military vessels of decades previous.⁴³ Connected to both the imperial metropole and the colonial periphery, they facilitated the movement of knowledge between them. The delicate astronomical equipment was stowed away below deck for the duration of travel, and Eddington mentions no work of note being carried out while they were in transit. In comparison to the voyages of Cook, which involved months of sailing at a time, the technologies of steamship travel meant the journeys to West Africa and across the Atlantic were only a matter of weeks, giving the astronomers little reason to risk damaging their fragile equipment by unloading it while traveling. Despite the lack of scientific activity on board, these ships nevertheless played a significant role in facilitating the movement of the astronomers between the locations at which their science was prepared and produced.

Disembarking briefly at Lisbon en route, the astronomers were greeted by Dr. Frederico Tomás Oom, an astronomer of the Lisbon Astronomical Observatory (OAL). Some contact had taken place between the OAL and the British astronomers after Príncipe had been selected as a potential site for observations amid concerns that political turbulence in Portugal, which had only become a republic eight years previously, might affect the viability of traveling to one of its island colonies.⁴⁴ Connections to their Portuguese counterparts served the British astronomers well; their shared astronomical interests provided a platform from which discussions on details such as accommodation, travel arrangements, and local geography could arise. Dr. Oom himself

was a veteran of previous solar eclipses, having coordinated many of the arrangements for foreign observers in Portugal during an eclipse in May 1900.⁴⁵ Along with the Portuguese vice admiral, he was to make sure Eddington and Cottingham were greeted hospitably at Príncipe, and that their work could take place in comfort. Established sites of astronomical science across the world such as the observatories at Lisbon and Rio de Janeiro played an important role in facilitating the scientific program of the British astronomers. As part of a global network of astronomical science, they acted as conduits for regular contact and dissemination of information related to the eclipse. These institutions impacted the plans of Eddington and his colleagues not just through the circulation of astronomical knowledge but also, as will be discussed in the following section, through the political and geographical knowledge of the locations at which the British astronomers planned to make their observations.

THE SITES OF OBSERVATION

Príncipe

The movement of scientific knowledge between the colonial periphery and the European metropolises is a significant area of study in the history of science, particularly during the second half of the nineteenth century when British imperial rule across the world was at its peak. Suman Seth's comment that "colonial holdings were crucial for the development of astronomy" sums things up neatly. The late Victorian era had seen a number of eclipse expeditions to lands under colonial rule including India. Here, astronomers could take advantage of an established system of colonial astronomy including observatories and the physical presence of imperialism including administrators and translators to make observations before transmitting their results home to the astronomical centers in Britain.⁴⁶ Unlike India, however, Príncipe was not home to numerous observatories or a dedicated community of astronomers. The astronomers traveling to Príncipe did, however, benefit from an imperial infrastructure before returning home with their findings, with the legacies of Portugal's imperial presence on the island having a tangible effect on where Eddington and Cottingham could carry out their work.

Despite passing comments on the socioeconomic conditions that existed on Príncipe at this time, little has been written connecting these conditions to the ability of the British astronomers to make their observations.⁴⁷ While the expedition was to be heralded as a success, and a triumph for international cooperation in the name of science, existing accounts have overlooked how the observations made at Príncipe were the result of using space that was characterized by colonial practices.⁴⁸ By utilizing the facilities available to them at the Roça Sundy plantation, the astronomers were taking advantage of spaces that had been acquired and managed as Portuguese colonial territory in Africa. Príncipe and neighboring island São Tomé were integral to Portugal's plans for retaining an imperial presence in Africa after the 1890 Ultimatum, in which they were forced to cede territory to the British Empire.⁴⁹ Like the other European empires of the Victorian era, the Portuguese exploited their colonies for their natural resources. In the case of Príncipe, cocoa plantations dominated the island's landscape. The people, too, were exploited, with the plantation workers under the control of the Sociedade de Agricultura Colonial (SDC) and the Portuguese officials who were able to build lavish homes in the most desirable areas of the island. These islands had been major cocoa producers in the late nineteenth and early twentieth centuries, and despite Portugal outlawing slavery in its colonies in 1858, by the turn of the century the workers on these islands were still subject to strict contracts that they had little knowledge of or control over.⁵⁰ English chocolate manufacturer Cadbury's was embroiled in controversy over the working conditions of the people used to harvest the cocoa on these islands, many of whom were imported from nearby Angola. Following the investigation of the cocoa industry in the colonies by Joseph Burt, a Quaker and member of the British Anti-Slavery Society sent on Cadbury's behalf, working contracts were improved with government regulations set up to control the recruitment and repatriation of laborers. Conditions improved significantly by 1916 just as the controversy "faded into obscurity" at the outbreak of the Great War.⁵¹

Eddington and Cottingham arrived on Príncipe on April 23, more than a month after they had left Crommelin and Davidson, who stayed on board the *Anselm* sailing to Brazil. Dr. Oom and the vice admiral made good on their promise to see the astronomers welcomed favorably at Príncipe, and upon arrival they were met by a selection of the

island's administrators. These included Sr. Vasconcelos, the acting administrator of the island; Sr. Grageira, who represented the SDC; and Sr. Carneiro, the president of the Association of Planters and the owner of the largest private plantation on the island, who would host them. With these men were the island governor; the judge of the island court; the harbormaster; the *curador*, a young man in charge of importing labor to the island; the government treasurer; a clerk in the employment of Sr. Carneiro; Sr. Atalaya, the manager of Roça Sundy, where Eddington and Cottingham would be staying; and Messrs. Lewis and Wright, two English-speaking men from Sierra Leone who were the staff of the local cable station and acted as interpreters between the men.⁵² The welcome from these men lends a diplomatic tone to proceedings. With no scientific counterparts to meet, the British astronomers instead established friendly relations with the colonial administrators of the island. Ruth Craggs has highlighted how hospitality was an important factor in imperial and postcolonial international relations, noting that "hospitality could both strengthen connections between European communities across empires and legitimate and facilitate a European presence in the colonies."⁵³ Such work is applicable here, as the hospitable nature of the Portuguese colonial administrators on Príncipe provided a welcoming environment for the astronomers to do their work, with astronomy acting as a diplomatic tool with which to bridge divides in language and occupation.

With pleasantries out of the way, the astronomers' attention turned to deciding where the eclipse observations could be made. The geographical attributes of Príncipe must be considered in close detail to demonstrate how the astronomers chose their viewing site. While the coastal areas of Príncipe are relatively low-lying, the center of the island is dominated by a high mountainous region, which causes the formation of clouds. Príncipe was dotted with *roças* (plantations) under the control of the SDC, and these offered the best chance to find a large enough clearing to establish a viewing site among the jungle-dominated landscape. The Sundy plantation where Eddington and Cottingham stayed was "situated in the north-west of the island overlooking the sea at a height of 500 feet, and as far as possible from the cloud-gathering peaks."⁵⁴ Other potential locations for establishing their base of operations had been visited: Roça Esperanza, home of Sr. Grageira, was deemed to be too hemmed in by the surrounding mountains, while Roça San Joaquin in the south

would have been fine were it not for the availability of the exemplary Roça Sundy. There was “little difficulty” in deciding that Roça Sundy was the best place for their observations. Describing it to his mother, Eddington wrote that “it is sheltered to the east by a building and is open towards the sea on the west and the north—just right for the eclipse.”⁵⁵ Here, Eddington and Cottingham were able to erect their instruments on flat, stable land without fear of disturbance, while staying close at hand in the luxuriant Sundy plantation house owned by Sr. Carneiro. As imperial spaces, colonial plantations have been of interest to historians for their role in imperial trade networks, the political influence they carried with them for the ruling elite, and how their workforces were subject to exploitative conditions.⁵⁶ Here, the plantation is a space where the cultures of empire and science interweave. The landscape, cultivated as it was for colonial agriculture, also provided a suitable place for the scientific inquiry of British astronomers, and the plantation’s local workforce provided extra assistance when required. Sundy’s close proximity to the coastline also presented the astronomers with almost the exact geographical conditions suggested by John Evershed during planning.

While Eddington’s and Cottingham’s local assistants were not versed in the nature of eclipse expeditions, their importance should in no way be underestimated. The influence of the island officials is apparent throughout the eclipse work, with the intimate knowledge of Príncipe’s geography shared with the astronomers by Sr. Grageira and Sr. Atalaya enabling them to establish a station for observations in the most appropriate place. Sr. Carneiro was an accommodating host, providing the astronomers with “ample resources of labour and material at Sundy.” Sr. Atalaya, the manager of the plantation on which they stayed for the duration of their time on Príncipe, was “invaluable” in his help and attention, and Messrs. Wright and Lewis, who “kindly assisted us as interpreters when necessary,” all played important roles in ensuring the work of the astronomers could take place. These men made “all necessary arrangements” for Eddington and Cottingham, and even dispensed with the usual customs examination of their luggage.⁵⁷ Eddington is exuberant in his praise for their hosts on Príncipe and their assistance in providing such a promising location from which they could observe the eclipse. There was a clear sense that their hosts wanted to assist the astronomical work in every possible way, by easing the British

astronomers into their surroundings while they stayed on Príncipe. Sr. Carneiro's help in offering his land for the purposes of the expedition is singled out for special praise by Eddington, who also cites his decision to postpone a trip to Lisbon so that he could personally welcome the two astronomers to the island.⁵⁸ These cordial relations between the British astronomers and the Portuguese colonial administrators in this peripheral European colony were a crucial factor in determining the success of this expedition, and allowing the movement of the critical scientific results between the Portuguese colony and the British scientific centers.

Portuguese control over the island created a degree of Eurocentric cooperation that may not have been afforded to the astronomers had the island been an autonomous state, or part of a nation that had not been subject to colonial influences in its infrastructure and governing. These influences are particularly visible in Eddington's account of their time on the island. Little is mentioned of any difficulties experienced in finding assistance to help set up their equipment or acquiring the resources necessary to complete the expedition, suggesting that everything was catered for appropriately. Eddington notes that there were over six hundred native workers on nearby plantations who could be called to assist with any need for physical labor.⁵⁹ Their luggage was transported from the port to Roça Sundy by tram, save for a small portion of the journey where the luggage was carried by local workers through wooded areas. Reaching their desired viewing location was a challenge due to the hilly, forested terrain of the island. While eclipse expeditions had historically been planned with ease of access to viewing sites in mind, often placing the final locations near a railway line, for example, occasionally—as was the case on Príncipe—there was some difficulty in transporting the equipment from the docks to the appropriate place from which observations could be made. Príncipe was not appropriately equipped throughout for the transport of delicate astronomical instruments and thus the astronomers relied on the native laborers to share their own knowledge, skills, and labor to aid the progress of the expedition. The assistance of previously omitted characters such as the native plantation workers proved to have been a significant help to the astronomers. However, there is little mention of these people in the records of the expedition, save for vague references to the labor they carried out, relegating them to the role of the “invisible technician” discussed by Steven Shapin.⁶⁰

The scientific work undertaken by Eddington and Cottingham on Príncipe was built on a foundation of hard labor. They owed a great deal to the unnamed workers who helped construct viewing platforms for their telescopes and transported the instruments to the plantation from the port. By highlighting how West African laborers could contribute to eclipse expeditions in the early twentieth century, this study further substantiates the work of historical geographers such as Felix Driver and Lowri Jones, who offer a compelling argument for the inclusion of local workers, guides, and interpreters in accounts of European exploration and scientific progress.⁶¹ Such individuals were integral to the astronomers' ability to navigate Príncipe and grow familiar with their surroundings in order to establish a favorable site of astronomical activity.

The cooperation between Great Britain and Portugal in this instance also reflects larger-scale trends in international political relationships at this time. International cooperation experienced a resurgence following the end of hostilities in 1918, with the League of Nations being formed shortly afterward and a renewed drive toward the completion of multinational projects, including the International Map of the World.⁶² Such cooperation is demonstrated by the Portuguese in charge of the Roças on Príncipe, whose enthusiastic welcome portrayed an island colony that was friendly, civilized, and productive, thereby signaling features of a strong, or at least resurgent, Portuguese empire that could coexist amenably among its European allies and was not guilty of defying international regulations regarding slave labor.⁶³ By enlisting the laborers on Príncipe to transport luggage and the instruments, and to help build and dismantle the viewing piers for the instruments, the British expedition party availed of a system of labor that had been built around an outdated culture of slavery and was a direct consequence of Portugal's earlier imperial ambitions. Indeed, the entire infrastructure of São Tomé and Príncipe was molded by the establishment of plantations, and consequently the presence of high-ranking colonial officials to ensure that industry on the islands was profitable and efficient. The ways native workers were managed by colonial administrators on Príncipe and their involvement in the physical work necessary for this astronomical science supports Helen Tilley's view of colonial Africa as a "living laboratory." This conceptualizes Africa as a place where the practice of science enacted an interplay between processes of colonialism and scientific study, influencing not only the development of societies in the colonies

but also the effect such science had on the metropolises of Europe.⁶⁴ The administrative help of the Portuguese government and the SDC enabled the astronomers to use spaces such as Roça Sundry to create a controlled site of scientific practice, something that would otherwise have been impossible without the widespread colonial influence on the island.

Framing this half of the expeditions within its local political and social contexts allows us to see how astronomical science became not just concerned with the celestial mechanics of the sun and the moon above but also geographically contingent on the social, economic, and political cultures of the spaces in which the science was being performed. Similar to how Jane Camerini describes the ways other scientific enterprises to far-flung colonies had benefited from the social classes of a “dislocated European society,” the astronomers found the colonial presence on Príncipe to be particularly welcoming and advantageous.⁶⁵ Supporting arguments put forward by Peter Redfield, who has referred to the “shadow of empire” on the island of French Guiana, where a former colonial outpost became home to the industries of outer space, the island of Príncipe also played host to both colonial practices and astronomical science, and the interaction between these.⁶⁶ Studying the processes involved with the operations of the expedition reveals a network of actors, places, and instruments that each had a specific role in helping the expedition reach a point of success. While the majority of Eddington and Cottingham’s contact was with the plantation owners and government officials, they also benefited from the help of local workers and the social, political, and economic characteristics of Príncipe that shaped their lives.

Unfortunately, despite securing what was a suitable site in geographical terms, issues of climate caused some uncertainty for the eclipse work. In the astronomers’ official report, specific reference is made to the *gravana*, the seasonal weather that occurs on Príncipe roughly between May and August. The *gravana* is characterized by little rainfall and lower temperatures than the rainier, warmer season that is predominant on the island for most of the year and better represents its equatorial position. The astronomers note that the *gravana* is “generally accompanied by increased cloud,” which caused some difficulty in making observations despite mostly clear skies during their first week on the island.⁶⁷ Despite the eclipse occurring during the *gravana*, the morning of the eclipse saw the heaviest rainstorm of their stay on

Príncipe, a “remarkable occurrence at that time of year.”⁶⁸ The days preceding the eclipse had been mostly cloudy, and while the rainstorm cleared some of this cloud cover briefly, it clouded over again slightly just as the eclipse occurred in the early afternoon of May 29. Despite this misfortune causing many of their plates to be rendered useless, Eddington and Cottingham were able to successfully produce two check plates, one of which agreed with Einstein’s theory of relativity by showing the altered position of several stars due to the sun’s gravity bending their light. Even with the bad weather, the geographical features of the site at which the astronomers were based enabled them to carry out the very precise observations that were required. Fortunately, the wise foresight of Dyson, who had seen the opportunity for two expeditions, meant that the British astronomers were not relying on the results of one expedition. The following section will show that the Brazil party had much more luck with the weather in Sobral.

Sobral

The other half of the British efforts to view the eclipse of May 1919 saw Dr. Andrew Crommelin and his assistant, Mr. Charles Davidson, travel to Sobral, a town in the northeastern state of Ceará, Brazil. The path of the eclipse began in western Brazil, and Sobral offered a suitable location in the east of the country to view it just before it passed into the Atlantic Ocean. To get there, Crommelin and Davidson continued aboard the *Anselm* from Madeira. The Booth Line served as one of the more popular shipping passages for travel to South America from Great Britain, with extensive port infrastructure in Brazil and regular departures suiting the British eclipse expedition perfectly for traveling to Sobral. Sobral itself had appealed to astronomers because of the good transport connections described by Dr. Morize’s circular. The astronomers passed into Brazil unhindered, arriving at Pará (a state northeast of Ceará) on March 23, and they were able to take their cases through customs without inspection thanks to help from the British consulate. After a month of relaxed sailing on the Amazon, they left Pará and arrived in Ceará on April 24, bound for Sobral aboard the *Fortaleza*, a local steamer. Five days of further travel brought them to the coastal port of Camocim, where a train took the astronomers inland to Sobral on April 30, with their luggage following them the next day.⁶⁹ Like their

counterparts in Príncipe, Crommelin and Davidson were met by various figures of local authority upon arrival at Sobral station. Among these were Dr. D'Oliveira and Monsignor Ferreira, representatives of the civil and ecclesiastical authorities of Sobral, respectively. Jesuit astronomer Father Cortie, who had originally been part of the Sobral expedition, had arranged for the religious authorities in Sobral to give the British party a warm welcome upon arrival.⁷⁰ From the station they were taken to the house of Colonel Saboya, the deputy of Sobral, who had given the two astronomers use of his house during their stay. Establishing contact with the relevant authorities in Brazil before commencing the expedition gave the British astronomers reliable and friendly assistance there upon arrival. Dr. Leocadio Araujo of the State Ministry of Agriculture was singled out for special praise by Crommelin and Davidson. Acting as their interpreter, Dr. Araujo was vital in answering their queries and addressing any problems that arose, with Crommelin writing that "his services were invaluable, and contributed greatly to our success, as also to our well-being during our stay."⁷¹ The willing cooperation of the civic authorities in Sobral was of great importance to the astronomers, as their local knowledge and provision of facilities and labor was critical in providing a suitable place to view the eclipse.

Just as in Príncipe, the geography of the site chosen for observations reveals a space within which the astronomers could attempt to recreate observatory conditions for viewing the eclipse. Fortunately, their accommodation presented an opportune location from which to do just that. As Crommelin described in his report,

A convenient site for the eclipse station offered itself just in front of the house; this was the race-course of the Jockey Club, and was provided with a covered grand stand, which we found most convenient for unpacking and storage and in the preparatory work.⁷²

The covered grandstand alongside the racecourse provided a shaded area where the instruments could be kept sheltered when not in use, and Colonel Saboya's house also provided the astronomers with a steady supply of water, used in the process of developing the photographs. Dr. Morize, who had visited Sobral a month before the British expedition party, had arranged for a supply of labor to be at the control of the two astronomers, including bricklayers, porters, and carpenters. Dr. Araujo was able to explain the astronomers' "complicated" demands to the local

workforce, provide meteorological data, and help the local municipal authorities prevent people from nearby residential areas from entering the racecourse. This prevented any potential interference with the equipment or measurements, further depicting this site as a controlled area of scientific practice.⁷³ The precise measurements that were needed meant that as little disturbance as possible was desired by the astronomers. Despite their exclusion from the grounds of the observing parties, the locals maintained a keen interest in the astronomical affairs taking place. The eclipse became a public event in Sobral, with the townsfolk being able to purchase a ticket (for ten thousand réis) to view totality briefly through telescopes set up in one of the town squares (fig. 1), and materials printed to show the path of the eclipse across Brazil.

Weather at Sobral was mostly settled, but they were met with “scanty” rain throughout their stay, with sudden afternoon downpours “ushered in by a violent gust of wind.” Their location six miles southeast of Mount Meruoca, with a height of 2,700 feet, meant that the majority of the cloud cover was collected by the mountain, with the summit “being frequently veiled in mist” resulting in a poor observation site despite its elevation.⁷⁴ The daily temperature did not vary a great deal, and the astronomers found that one brand of plates they had brought with them was unsuitable in the warm temperatures. This was not the only problem they had with excessive heat. High temperatures during the day caused the mirror of one of the coelostats to distort, causing many of the images taken using the 16-inch astrographic to lose focus.⁷⁵ On top of these issues with temperature, their viewing location was also troubled by wind. The astronomers “had reason to fear strong gusts about the time of totality, such as had occurred at other eclipses.” Therefore, it was decided that protective windscreens should be erected around the huts wherever possible.⁷⁶ One of their viewing huts was even overturned by a particularly strong gust of wind during preparations, but the damage was “quickly and skilfully repaired” by the carpenters that had been placed on hand to help construct the viewing apparatus.⁷⁷

The changeable conditions at Sobral meant that it was all the more important that the astronomers could use a site such as the racecourse to set up their field observatory (fig. 2). The flat ground, the nearby covered grandstand, and the close proximity of their accommodation—not to mention straightforward access to the various materials they needed for the construction of brick piers and windscreens—allowed

FIG. 1. A ticket available in Sobral on the day of the eclipse. The ticket holder was able to view totality from Senator Figueira Square for a period of one minute only. Royal Greenwich Observatory Archives, Papers of Sir Frank Dyson, RGO 8/150. Reproduced by kind permission of the Syndics of Cambridge University Library.

the astronomers to easily negate any disruptive climatic conditions that had the potential to spoil observations. To quote Robert Kohler's work on the laboratory-field border, the astronomers managed to "assimilate elements of laboratory practice and make them appropriate to field conditions."⁷⁸ Here, the boundary between astronomical laboratories such as observatories and the viewing site in the field becomes blurred, as the astronomers, assisted by outside actors, were given the opportunity to recreate as closely as possible the ideal conditions within which to view the eclipse using established techniques honed in Britain and adapted to the more tropical location at which they were based. The intermediaries in Sobral, just like their counterparts in Príncipe, were able to minimize potential disturbance in the recording of scientific observations, something that had commonly plagued explorers and scientists in the field over many previous decades.⁷⁹ Fortunately, these many precautions were not needed in the end, as "dead calm prevailed at the critical time."⁸⁰ During the eclipse, Dr. Araujo played an important role in ensuring that exposure times were precisely measured, by counting out every tenth beat on a metronome for the duration of totality. The astronomers captured images on eight plates using the 4-inch telescope, with Crommelin noting they "are much more hopeful for a possible result" after seven of the plates showed seven stars with clear definition.⁸¹ Once the development of the photographs taken with the 16-inch astrographic was complete, they stowed their instruments safely inside Colonel Saboya's house until July 9 to make comparison photographs of the eclipse field, which took approximately one week. Taking comparison photographs of the same area of the night sky that had been eclipsed allowed the astronomers to see the positions of the stars as they appeared regularly, without alteration from the presence of the sun. With these photographs at hand, the extent of the deflection of starlight caused by the eclipse would become clear.

Like their counterparts in Príncipe, Crommelin and Davidson had found the opportunity to conduct their astronomy heavily influenced by local resources and geographies. They used the official report to mention their gratitude to Mr. Charles Booth and his shipping company "for facilitating their journeys to and from their station at a difficult time," along with making arrangements to forward their luggage from Pará to

FIG. 2. The 16-inch astrographic (left) and the 4-inch telescope (rear) with their coelostats (front) as they were set up in Sobral. Astrographic telescopes were used to photograph stars and other faint celestial phenomena, while the coelostat was a slowly turning mirror designed to continuously reflect part of the sky into the telescopes. Just as in Príncipe, these instruments and their accompanying huts and concrete stands required large open spaces and flat, stable ground on which to operate accurately. Image courtesy of the Science and Society Picture Library, Science Museum, London.

Camocim and on to Sobral, free of charge.⁸² Thanks were also made to the Brazilian government and Dr. Morize, who made “most complete arrangements for the expedition, and in this way contributed materially to its success.”⁸³ Brazil’s developed transport infrastructure allowed ease of movement across the country, while established cultural and economic infrastructures gave the British astronomers comfortable surroundings and access to the resources they required to carry out their scientific work as they had planned it. Drawing on Bruno Latour, we can see how the British astronomers traveled and worked through carefully managed networks of which local civic authorities and appropriate spaces such as the racecourse were part of, allowing them to conduct their science.⁸⁴ Combined with the ability to mitigate unfavorable climatic conditions when they occurred, these factors allowed Crommelin and Davidson to produce seven images with the 4-inch telescope at Sobral. These images

were the most in favor of Einstein, as they showed the altered positions of several stars as had been predicted by his theory.

CONCLUSION

The results of the expeditions were met with fanfare in the British press, with the headline in the *Times* declaring a “Revolution in Science.”⁸⁵ While Einstein was eventually lauded for his theories, and Eddington and his associates cemented their place in the history of science for their role in proving them, little of this had any lasting impact on the places at which the science was carried out. In Príncipe, it was not until ninety years later that a plaque was erected to mark the island’s role in the expeditions.⁸⁶ The reception of the scientific endeavor post-expedition reflects the nature of the metropole-periphery boundary that defined much of the work of the astronomers in the tropics. The astronomers relied on the imperial presence of plantation owners and their laborers in Príncipe to carry out their work. However, the astronomical work that took place there was planned at the RAS in London, and the resultant observations were discussed and debated across the scientific centers of Europe. Despite their crucial role in facilitating the needs of the astronomers, only a brief display of gratitude to the authorities in Príncipe and Brazil was included at the end of Eddington and Dyson’s official report to the RAS.⁸⁷

The astronomical science that would go on to confirm Einstein’s theory did not take place in a vacuum; rather, it was the result of established scientific practices being influenced by a range of geographical factors, including the spatial characteristics of the sites they chose and the shipping routes they used for travel. Being the first expeditions to have successfully tested the deflection of starlight, these expeditions show that despite changing lines of inquiry for astronomers in this period, the expedition remained an important tool for their research. These expeditions were intrinsically spatial endeavors and cannot be untangled from the geographical factors of their production. The planning stages of the expeditions at the RAS brought together a range of astronomical and geographical knowledge from astronomical institutions across the world, showing us that astronomers relied on a global network of astronomical knowledge to thoroughly plan their expeditions. The networks of commercial shipping also played an

important role in the movement of astronomers from their bases in Britain to the viewing locations in the tropics, with the shipping routes providing easy access and short periods of transit. The changing face of imperial relations in Europe and the disturbance of the First World War shaped the astronomers' methods of travel, and the use of steamships such as the *Anselm* and the *Portugal* demonstrates that the mobilities of astronomical fieldwork were heavily influenced by popular commercial shipping routes and their associated infrastructures. This allowed astronomers to move away from a reliance on military ships, which had been common in the nineteenth century, as astronomical fieldwork began to detach itself from the imperial modes of transport and conduct that had characterized earlier work. However, as the observation site on Príncipe shows, expeditionary astronomy could not detach itself completely from imperial legacies in this period. To achieve the ideal viewing conditions in the field, the astronomers relied on the help of colonial administrators in Portuguese-controlled African territory, using the plantation grounds that offered the most suitable geographical characteristics for making observations. At Sobral, appropriate viewing conditions were created for the astronomers as they were given the assistance of local officials and the materials and space they needed to practice their science free from distraction.

The story of these expeditions features a diverse set of spaces, from the meeting rooms of the RAS to the plantation viewing site on Príncipe. The local knowledges shared at each of these played a significant part in how this science was planned at home and produced in the field. Giving these spaces due attention also helps illuminate the roles of the people who occupied them and how they were able to assist in the work of the expeditions. To gloss over the locations at which the astronomers studied the eclipse is to minimize the contributions to the scientific endeavor of men such as Sr. Carneiro, Sr. Atalaya, and Dr. Araujo, along with the other administrative officials and civic authorities of Príncipe and Sobral. It also minimizes the important role of the local laborers in these places, as well as the staff of the ships on which the astronomers traveled and the people that worked in their hosts' houses. While it is often difficult to recover information about these people, each of them contributed to the success of these expeditions. In the case of Príncipe in particular, given that so little was known about any potential viewing sites prior to their arrival, the success of British astronomers was

predicated on their hosts providing them with a space at which they could carry out their observations, along with the provision of labor to assist in the preparations. Managing these spaces was also key, as the local conditions of the sites at which these observations took place affected the instruments the astronomers used and the observations they could make, evidenced by the heat distortion of the coelostat in Sobral and cloudy weather on Príncipe. The mitigation of these factors, through the beneficial geographies of local landscape and labor, meant that the precise measurements needed could be obtained.

Together, these different factors provide an insight into how expeditionary astronomy in the early twentieth century was geographically contingent in both its production and its execution. These factors were essential in creating the conditions needed to make the observations and demonstrate that local knowledge, histories, and geographies had a fundamental role to play in what would become revolutionary global science.

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NOTES

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