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Einstein in Portugal: Eddington's expedition to Principe and the reactions of Portuguese astronomers (1917–25)

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Abstract. Among various case studies addressing the reception of relativity, very few deal with Portugal at either the international or the national level. The national literature on the topic has mainly concentrated on the reactions to relativity of the Portuguese mathematical community. The absence of Portuguese astronomers alongside Eddington during the 1919 expedition to Principe, then a Portuguese island, has been implicitly equated with the astronomical community's lack of interest in the event. In reception studies dealing with general relativity, analysis has tended to focus on the physics and mathematics communities, less on the astronomers. Given that relativity was born at the interface of physics, mathematics and astronomy, reactions of members of these scientific communities depended on differences in shared traditions, values, problems and expectations, as well as on individual practitioners' idiosyncrasies. This paper addresses the contributions of the overlooked Portuguese astronomical community, evaluates the actions and reactions of its members to the expedition and assesses their role in the process of appropriation of relativity.

At the end of the joint communication presented by F. W. Dyson, A. S. Eddington and C. Davidson to the joint meeting of the Royal Society of London and the Royal Astronomical Society on 6 November 1919, the authors thanked the Brazilian government and the Brazilian astronomer and head of the Rio de Janeiro Observatory H. Morize (1860–1930) for their hospitality and help during the expedition to Sobral. In the case of the parallel expedition to the Portuguese island of Principe, they thanked two locals, the plantation landowner Jerónimo Carneiro and his foreman, Atalaya.[1] A couple of years later, en route to his tour of South America, Albert Einstein stopped in Lisbon and strolled around to get a flavour of the Portuguese capital. In his diary entry for 11 March 1925, Einstein described his first impressions of the city, its women and monuments. The city looked 'scruffy but nice', a woman with a basket of fish on her

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1 F. W. Dyson, A. S. Eddington and C. Davidson, 'A determination of the deflection of light by the sun's gravitational field, from observations made at the total solar eclipse of May 29, 1919', *Royal Society of London, Philosophical Transactions* (1920), **A220**, 291–333.

head and a mischievous but proud look caught his attention; he enjoyed the castle and the cloister of the Monastery of Jerónimos.[2] No scientists, nor any of the local elite (Jewish or otherwise), greeted him.[3] Yet a euphoric reception awaited Einstein in Brazil. Both episodes point to a telling contrast between the presence of the Brazilian scientific community and the absence of that of Portugal.[4]

Among various case studies that address the reception of relativity very few deal with Portugal at the international or national level.[5] The national literature on the topic has concentrated mainly on the reactions to relativity of the Portuguese mathematical community,[6] and the absence of Portuguese astronomers alongside Eddington has been implicitly equated with the astronomical community's lack of interest in the event. Generally, in reception studies dealing with general relativity, analysis of reactions has tended to focus on the physics and mathematics communities and less on the astronomy community.[7]

This paper addresses the contributions of the neglected Portuguese astronomical community, evaluates the actions and reactions of its members to the expedition and assesses their role in the process of appropriation of relativity during the period starting in 1917, which witnessed the first reference to general relativity and Portuguese astronomers' discussion of the forthcoming 1919 total eclipse, and concluding with Einstein's stop in Lisbon on his way to South America in 1925.[8]

Eddington had corresponded over the years with the astronomers of the Observatório Astronómico de Lisboa (OAL – Astronomical Observatory of Lisbon). He acknowledged their assistance in the joint communication in the section on the expedition to Principe. On their way to the tropical island, Eddington and his partner

2 A translation into Portuguese of Einstein's travel to South America is included in A. T. Tolmasquin, *Einstein – O Viajante da Relatividade na América do Sul*, Rio de Janeiro, 2003.

3 Einstein had a few correspondents in Portugal, mostly scientists and members of the Jewish community. In the period under consideration in this paper, his only correspondent was Mário Basto Wagner (1887–1922), a young physicist who died at the age of thirty-five. Albert Einstein Archives, The Jewish and National University Library, Jerusalem.

4 Tolmasquin, op. cit. (2); I. Castro Moreira and A. A. P. Videira (eds.), *Einstein e o Brasil*, Rio de Janeiro, 1995; C. M. Silva da Silva, 'Recepção da teoria da relatividade no Brasil, entre 1919 e 1934', *Revista Brasileira de História da Matemática* (2005), **5**, 57–79.

5 See T. Glick, *The Comparative Reception of Relativity*, Dordrecht, 1988 and references therein. Reception case studies include countries such as the USA, the UK, France, Germany, Italy, Spain, the USSR, Poland and Japan.

6 D. Lopes Gagean and M. Costa Leite, 'General relativity and Portugal: a few pointers towards peripheral reception studies', in *Studies in the History of General Relativity* (ed. J. Eisenstaedt and A. J. Kox), Boston, 1988, 3–14; A. J. Fitas, 'A Teoria da Relatividade em Portugal no Período entre Guerras', *Gazeta de Física*, (2004), **27**, 4–10; *idem*, 'A Teoria da Relatividade em Portugal (1910–1940)', in *Einstein entre nós. A recepção de Einstein em Portugal de 1905 a 1955* (ed. C. Fiolhais), Coimbra, 2005, 15–42.

7 A recent exception is J. Crelinsten, *Einstein's Jury: The Race to Test Relativity*, Princeton, 2006, a book in which the author addresses the reactions of the American astronomical community towards general relativity. The book builds on the author's Ph.D. dissertation written more than twenty years ago.

8 E. Mota, A. Simões and P. Crawford, 'Einstein em Portugal: o primeiro teste da teoria da relatividade geral e o seu impacto na comunidade científica nacional', in *Einstein entre nós. A recepção de Einstein em Portugal de 1905 a 1955* (ed. C. Fiolhais), Coimbra, 2005, 43–56; E. Mota, 'The 1919 Expedition to Principe: Appropriation of Relativity by the Community of Portuguese Astronomers' (in Portuguese), M.Sc. thesis, University of Lisbon, 2006, unpublished.

E. F. Cottingham, together with Davidson and A. C. Crommelin, stopped in Lisbon and all climbed one of its steep hills to visit the observatory. We pay particular attention to the group of astronomers of the OAL not only because they were Eddington's contacts, but also because they were able to stimulate a network of astronomers centred around those who worked at the OAL or were trained there, at the same time as being actively involved in the creation and development of other observatories.

The only Portuguese astronomer who tried to join the British expedition to Principe, without any success, was Manuel Peres (1888–1968). He was then the director of the Observatório Campos Rodrigues (OCR – Campos Rodrigues Observatory) located in the Portuguese African colony of Mozambique, and named after the second director of the OAL, a central figure in the promulgation of a scientific project for this institution.[9] This failure did not deter Peres from following the development of relativity and participating in its popularization. Others soon joined him. Most Portuguese astronomers were stimulated to adopt attitudes to relativity ranging from acceptance to rejection by those aspects of the theory that impinged on their scientific interests as practitioners; all then used their knowledge to take part in various forms of popularization. The astronomer Manuel S. Melo e Simas (1870–1934) is the sole exception to this trend. Besides participating in the work of popularization, he tried to incorporate relativity within his own scientific practice. He attempted to measure the bending of light rays bordering Jupiter's surface in order to find an extra confirmation of the light-bending prediction made by general relativity.[10]

The Portuguese astronomical context and the Portuguese astronomical community

At the beginning of the nineteenth century, astronomers typically engaged in measurement and prediction of planetary motions and determination of stellar positions. They were dependent on a small range of observational instruments, primarily telescopes with different mountings. These astronomical practices belonged to the realm of astrometry or positional astronomy.[11] To measure absolute star positions and times rigorously, meridian circles (telescopes aligned in the north–south plane) were widely used. Within their culture of precision, astronomers most valued accuracy, repetition and routine in the accomplishment of extended projects in which error analysis played an important role.[12] But by the last third of the nineteenth century astronomers had expanded their object of study considerably to incorporate investigation of the physical natures of the Sun, planets, stars and even nebulae. New observational technologies had entered the field. These included the great reflectors (telescopes of increased light-gathering capacity and resolution), astrophotographic equipment and, ultimately, the

9 OAL Archives. Ref. C-463 (1915–1929): Correspondence M. Peres/Oom (OAL).

10 M. S. Melo e Simas, 'Ocultação de uma estrela por Júpiter', *Jornal de Sciências Matemáticas, Físicas e Naturais da Academia de Sciências de Lisboa* (1926), **5**, 115–22.

11 R. W. Smith, 'Remaking astronomy: instruments and practice in the nineteenth and twentieth centuries', in *The Cambridge History of Science*, Vol. 5: *The Modern Physical and Mathematical Sciences* (ed. M. J. Nye), Cambridge, 2003, 154–73.

12 N. Wise (ed.), *The Values of Precision*, Princeton, 1995.

spectrograph. This 'new astronomy', also called physical astronomy, astrophysics or solar physics, assisted astronomers in their search for the physical and chemical constitutions of the Sun and other stars. Astronomical photography was largely responsible for the first areas of research in astrophysics. Early photographs of the Sun and Moon already showed a very fine level of detail. Pioneering work in this area focused on the granulation of the solar surface and on the periodicity of the sunspot cycle. The study of sunspots, a long-familiar form of solar activity, became vital to the emergence of solar physics and indicated a mysterious connection between the cyclic occurrence of solar magnetic storms and some magnetic episodes of certain kinds on Earth.[13]

Observations made during solar eclipses changed with astronomy's changing aims. Before 1840 astronomers' observational routines were particularly concerned with positions. The most important measurements were of the moments of the so-called 'contacts' of the Moon with the solar disc, particularly 'second contact', when totality begins, and 'third contact', when totality ends. These measurements led to refinements of the relative positions of the Earth, Moon and Sun, and were used for calculations in celestial mechanics. Absorbed as they were with the period of totality, astronomers did not notice other qualitative phenomena such as the corona and the chromosphere. From the point of view of positional astronomy, the observation of solar eclipses also had another aim. Astronomers expected to be able to explain the secular changes in the perihelion of Mercury by looking for the presence of intra-Mercurial planets.

The main interest in mounting expeditions to observe total solar eclipses at the start of the twentieth century had changed from astrometric to astrophysical purposes. It is within this framework that one should analyse Portuguese astronomers' motivations in launching or participating in solar eclipse expeditions. Portuguese astronomers were mainly distributed among three major observatories: the Observatory of Coimbra, the Observatório Astronómico de Lisboa, and the Observatório Campos Rodrigues in Mozambique, one of Portugal's African colonies.

The Observatory of Coimbra was created at the end of the eighteenth century in the context of the educational reforms promoted by the Marquis of Pombal. It was one among several affiliated institutions of the reformed University of Coimbra, including the Physics Cabinet, Chemistry Laboratory and Botanical Garden, all intended to embody Pombal's support for a modernizing experimental approach.[14] Specifically addressed to the practical teaching of astronomy, the publication of ephemerides gave the observatory considerable repute. But by the second half of the nineteenth century the observatory had entered a period of decline.[15] To reverse this awkward situation and at the same time to respond to the new trends in astronomy, Francisco Costa Lobo (1864–1945), astronomer, university professor and collaborator at the observatory,

13 J. North, *The Fontana History of Astronomy and Cosmology*, London, 1994, 465–9.

14 A. Simões, A. Carneiro and M. P. Diogo, 'Constructing knowledge: eighteenth-century Portugal and the new sciences', *Archimedes* (1999), **2**, 1–40; A. Carneiro, A. Simões and M. P. Diogo, 'The scientific revolution in eighteenth-century Portugal: the role of the *Estrangeirados* (Europeanized intellectuals)', *Social Studies of Science* (2000), **30**, 591–619.

15 P. J. da Cunha, *A Astronomia, a Náutica e as Sciências Afins*, Lisboa, 1929, 33.

embarked on an astronomical tour in 1907. He visited many European observatories with the aim of acquiring the necessary know-how and a spectroheliograph, to supplement the old photoheliograph and turn the observatory into a leading astrophysics centre in Portugal.[16] One of the most active astronomers in mounting solar eclipse expeditions in Portuguese territory,[17] he was a pioneer in the study of solar physics, specifically solar spots and prominences. Despite his enthusiasm the spectroheliograph did not reach Coimbra until 1925.

The OAL was founded in the second half of the nineteenth century, as a result of the international networking involved in the resolution of an astronomical controversy over contradictory determinations of the parallax of the star Groombridge 1830. The observatory's construction followed the suggestion of the astronomer Hippolyte Faye that a solution to the problem might depend on observations made in Lisbon using the zenithal telescope he had himself invented.[18] The OAL was designed in imitation of the observatory at Pulkovo. Its first director, F. A. Oom (1830–90) was trained by O. W. Struve, Pulkovo's director between 1858 and 1863. During the period of the eclipse expedition's preparation (1918–19), the OAL's director was the vice admiral and astronomer Campos Rodrigues (1836–1919), successor to F. A. Oom. Its vice-director was then Colonel Frederico Oom (1864–1930), son of its first director, and its staff included six astronomers and five auxiliary attendants. The astronomers' ages ranged from forty to eighty-two, the eldest being the director, Campos Rodrigues. Among them was the first-class astronomer Melo e Simas, who had been conscripted into the armed forces to participate in the First World War and was to return to the observatory only in October 1919.[19]

From its inception the observatory's scientific enterprise fell within the scope of positional astronomy and included stellar measurements as well as measurements of solar parallaxes. Sophisticated instruments had been acquired with an initially generous royal endowment, but by the turn of the century the observatory was operating under strained circumstances and was unable to take part in the transition in astronomical practices from positional astronomy to astrophysics, especially in connection with photographic techniques. However, the observatory was able to make its mark in international solar parallax programmes through the inventiveness of Campos Rodrigues, a true astronomer–*bricoleur*, and his ability to make ingenious improvements to various instruments, as well as through the industry and rigour devoted

16 F. M. Costa Lobo, *A Astronomia na Actualidade*, Coimbra, 1933.

17 Costa Lobo used the photoheliograph to make observations during the 1900 solar eclipse in the city of Viseu. He also reported on observations made during the eclipses of April 1912 and August 1914 and made a cinematographic recording of the first solar eclipse. Costa Lobo, op. cit. (16).

18 J. Silvestre Ribeiro, *História dos Estabelecimentos Scientíficos, Literários e Artísticos de Portugal nos sucessivos reinados da Monarchia*, Lisboa, 1871–93; F. Oom, 'O Observatório de Lisboa: sua influência na astronomia portuguesa', Discurso inaugural da 2ª secção, Astronomia e Física do Globo, *Proceedings do 1º Congresso Luso- Espanhol da Associação Portuguesa para o Progresso das Ciências e 8º Congreso de la Asociación Española para el Progreso de las Ciencias, Porto, 1921*, Madrid, 1921–3, 45–65; Cunha, op. cit. (15); P. Raposo, 'The life and work of the Admiral Campos Rodrigues' (in Portuguese), M.Sc. thesis, University of Lisbon, 2006, unpublished.

19 OAL Archives. 'Ofícios' (1905–21) – DA 256. Relação dos funcionários da Tapada (em 19 e 23 de Fevereiro de 1918 e Março de 1919) – idade – Pessoal Técnico. Relação dos astrónomos e do Pessoal auxiliar.

to every task by the sub-director, Oom.[20] This was the case during the 1892 Mars opposition and 1900–1 Eros observational campaigns respectively launched and coordinated by the US Naval Observatory in Washington and the Paris Observatory. Despite 'very modest instruments', the 'remarkable accuracy' of the observations of reference stars made during the Eros campaign led to the award of the 1904 Valz prize to Campos Rodrigues.[21] Apart from measurements of solar and stellar parallaxes, the observatory collaborated with the US Navy in a programme of longitude determinations of South American coastal sites (1878) and subsequent cartographic surveys directed by the naval officers H. Davis, F. Green and J. Norris.[22] Portuguese participation involved accurate longitude determinations of Lisbon, Funchal (on Madeira) and S. Vicente (in Cape Verde off the west coast of Africa).

From at least 1858 the observatory was also responsible for the Time Service. A pendulum clock determined the local solar time transmitted to citizens by a time ball installed in Lisbon harbour. In 1885 the first time ball was replaced by a new one,[23] and on the first day of 1916 the second time ball was replaced by the emission of a luminous time signal. Meanwhile, in 1913 the OAL acquired the necessary equipment to receive radio signals from the Eiffel Tower. Only after 1924 was a telegraphic time signal given by a Radio-Telegraphic Station mounted in Monsanto, Lisbon. Finally, the OAL also trained naval officers, including those despatched to duty in the African colonies as well as those in charge of geodesic determinations.

With respect to this Time Service, it is understandable that Oom, the sub-director of the OAL, was deeply involved in plans for the Astronomical Observatory of Lourenço Marques (now Maputo) in Mozambique, spending 1907 in a European tour to acquire instruments and become acquainted with the new time service installed in Hamburg harbour.[24] In a sense the project for the new observatory, with its emphasis on the Time Service, mirrored that of the Lisbon observatory. By 1919 the instruments held by the OCR were basically the same as those purchased at its foundation under the guidance of Oom.[25] Oom supervised the construction of the observatory (1908), stayed in Mozambique for eighteen months in 1908–9, and implemented a modern system for the dissemination of time in imitation of the Hamburg system.[26] The public clock was

20 P. Raposo, 'The astronomer/instrument maker Campos Rodrigues and the contribution of the Observatory of Lisbon for the 1900–1901 solar parallax programme', in *2005 Past Meets the Present in Astronomy and Astrophysics. Proceedings of the 15th Portuguese National Meeting* (ed. J. Afonso, N. Santos, A. Moitinho and R. Agostinho), Singapore, 2006, 97–100; Raposo, op. cit. (18).

21 Cunha, op. cit. (15), 30; Oom, op. cit. (18), 60. Henri Poincaré belonged to the awarding committee composed of members of the Academy of Sciences of Paris.

22 F. M. Green, C. H. Davies and J. A. Norris, *Telegraphic Determination of Longitudes on the East Coast of South America (1878–1879)*, Washington, 1880.

23 M. Silva and R. Agostinho, 'Time service and legal time in Portugal', in *2005 Past Meets the Present in Astronomy and Astrophysics. Proceedings of the 15th Portuguese National Meeting* (ed. J. Afonso, N. Santos, A. Moitinho and R. Agostinho), Singapore, 2006, 105–8.

24 Later Oom would supervise the plans for the construction of a similar observatory in Luanda, Angola.

25 M. Peres, *Relatório do Observatório Campos Rodrigues em Lourenço Marques de 1919*, Lourenço Marques, 1921, vol. 11.

26 F. Oom, *Projecto que serviu à construção do Observatório* '*Campos Rodrigues*' *em Lourenço Marques na Parte Astronómica*, Lisboa, 1916, 10.

therefore synchronized with the observatory's pendulum clock and marked official time. Using a pendulum clock to determine solar time, clock synchronization from 1916 depended on the emission of signals transmitted by wireless telegraphy. In this way the OCR became the first Portuguese observatory to use this innovative method of signal transmission.[27]

Besides this astronomical role the observatory collaborated in geographical missions for geodesic and cartographic mapping of colonial territories, often together with the Lisbon observatory. It also provided various meteorological services. The correspondence between Oom from OAL, Peres from OCR and the naval officer Carlos Gago Coutinho (1869–1959), in charge of the geodesic, topographic and cartographic programmes in the colonies of Mozambique, Angola and the islands of S. Tomé and Principe, is evidence of the intense collaboration between the two observatories.[28] In 1922 Oom was again selected to direct the project of construction of another observatory, this time in Angola. His aim was clear:

> we should be content in building in two of our capital cities in Africa, south of the equator, two institutions which in this particular scientific area will demonstrate that we do not forget our obligations as landlords as well as heirs to the oldest tradition of colonizers and navigators.[29]

In 1911 Oom and A. Ramos da Costa (1875–1939), naval officer, professor of astronomy and navigation at the Naval School and professor of topography and geodesy at the Army School, participated in the discussions preceding improvements in the Legal Time Service transmitted to Lisbon harbour. Besides his involvement with time determination, Ramos da Costa was an outspoken advocate of the necessity to start astrophysical observations and create an astrophysical observatory in Portugal.[30] With this project in mind he proposed the astrophysicist Louis Bauer, director of the Department of Terrestrial Magnetism at the Carnegie Institution of Washington, to become a corresponding member of the Academy of Sciences of Portugal, an institution founded during the Republic.

Solar eclipses and the reactions of the Portuguese astronomical community around 1919

Having briefly surveyed the Portuguese astronomical landscape with respect to the main observatories we now discuss the astronomers' participation in the organization of solar eclipse expeditions around and preceding the 1919 expedition, as well as their capacity and availability to take part in the event. F. Oom had been trained by Campos

27 OAL Archives. Ref. C-463 (1915–29), Correspondence M. Peres/F. Oom.

28 OAL Archives. Ref. C-231 e C-232: Various Correspondence and Ref. C-235: Scientific Correspondence; C. Machado, *Latitudes e Longitudes por Passagens meridianas de estrelas e cronómetros siderais*, Lisboa, 1917; Cunha, op. cit. (15), 33.

29 OAL Archives. Ref. DD-601 – Observatório de Luanda (1922–33), Relatório de Frederico Oom, 30 September 1922. This and subsequent translations, unless otherwise noted, are the authors' own.

30 R. da Costa, 'Necessidade de se iniciarem em Portugal as observações de Astrophysica', *Relatório dos Trabalhos da Academia de Sciências de Portugal (1914–1915)* (1915), **2**, 69–74.

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Rodrigues in the tradition of positional astronomy. A participant in expeditions to observe solar eclipses, he published regularly on the topic.[31] His papers were filled with accurate determination of contact times. Spectroscopic data and photographic plates from the solar corona were entirely absent from Oom's publications.[32] Although he agreed that the most important and recent researches were related to the spectral analysis of the chromosphere, solar prominences and the solar corona, he stressed that spectroscopic observations could only be made by experts with appropriate apparatus. Lacking such instruments, he stuck to positional astronomy and opted not to take part in the transition to astrophysics. This state of affairs reflected the scientific orientation of the observatory in which he spent his life and its unwillingness to face up to the changes in instrumentation responsible for the reform of astronomical tradition.

Aware of this change and its material implications, from 1905 he opposed the organization of expeditions on the grounds that they were only justifiable 'if astronomers are certain of achieving interesting scientific results, can acquire expensive instruments tailored for these observations, and are able to put forward new observational techniques'. For this reason 'unskilled astronomers with scant resources should only take part in these expeditions if they take place in Portuguese territory, in order to fulfil their obligation of collaboration'.[33] Much later, in the same spirit, he published a paper in 1917 in *O Instituto*, a scientific journal of the University of Coimbra, in which he discussed the circumstances of the upcoming solar eclipse of 29 May 1919. He invited Portuguese astronomers to study the geographical and climatic conditions of the eclipse, stated that the island of Principe was a convenient observational site and offered his calculations for contact times for a central point in the island.[34] It was in this context that he got in touch with Peres, director of the OCR since 1915.[35] Peres discussed with Oom the possibility of going to Principe and eventually joining the British team. In a letter of 18 November 1918 he said, 'By the way, is anyone from the [observatory at] Tapada [OAL] going to Principe? If yes is there a way of rescuing me? I would be delighted.'[36] However, by March 1919 Peres despaired of the fate of his letters. He worried about his sub-director, who had not yet returned from war-related tasks, and the diminishing probabilities of being at Principe in time for the eclipse:

> My visit to Principe looks unlikely. It is difficult to find a place on board, and it is necessary to make reservations greatly in advance. If I go officially I have right to a place, but if I go on leave the situation becomes difficult because I should take care of the ticket right away in order to

31 A list of the publications of F. Oom is included in M. S. Melo e Simas, *Elogio Histórico de Frederico Oom lido na assembleia extraordinária de 11 de Junho de 1931*, Coimbra, 1931; F. Oom, *Circunstâncias do eclipse total do sol de 1900*, Lisboa, 1900; A. J. da Cunha Júnior, 'Sessão ordinária de 4 de Junho de 1904', *Revista de Obras Públicas e Minas* (1904), 287–92, 289.

32 F. Oom, *Circunstâncias do Eclipse Anular-Total de 1912 Abril 17*, Lisboa, 1912; *idem*, *Previsões para o Eclipse Solar de 1916 Fev. 3 em Portugal e Ilhas*, Lisboa, 1915.

33 F. Oom, 'O Futuro Eclipse', *O Instituto* (1905), **52**, 487–90.

34 F. Oom, 'O Eclipse Total do Sol em 29 de Maio de 1919 visível na Ilha do Principe', *O Instituto* (1917), **64**, 97–8.

35 OAL Archives. Ref. C-463 (1915–29): Correspondence M. Peres (OCR)/Oom (OAL).

36 OAL Archives. Ref. C-463 (1915–29): Correspondence M. Peres (OCR)/Oom (OAL), letter, Peres to Oom, 18–20 November 1918, received by Oom on 17 January 1919.

> secure a place in the ship which leaves in the middle of next month. My idea is to ask for an unpaid leave, stop at S. Tomé, where I will stay for a month to be deducted from the leave spent in Lisbon. But unpaid leaves must be spent in the metropolis or in a place approved by the Health Committee and I doubt that S. Tomé will be approved. It remains the official visit. But this one seems unlikely as nothing arrived here so far and mail will not arrive on time. I asked the Governor to send a telegraph to the Ministry but no reply has been received as of today.[37]

In the end, Peres had to give up this project through lack of official authorization.

Campos Rodrigues died on Christmas Day 1919; Oom was promoted to director of the Lisbon observatory in 1920, the same year in which he became a member of the Academy of Sciences of Lisbon. Despite being an astronomer who published regularly in journals such as the *Observatory* and the *Astronomische Nachrichten*,[38] and in spite of having pressed Peres to participate in the expedition, Oom did not then refer either to the organization of the expedition or to its aims.[39] Neither Costa Lobo nor Ramos da Costa joined the British expedition to Principe. The reasons behind this fact are not known. While their astronomical practices and scientific trajectories point to their potential interest, some personal, institutional or financial reasons might account for their absence and may be taken as a sign of the weakness of the astronomical community in furthering its own scientific goals.

Costa Lobo was one of the most active participants in solar eclipse expeditions within Portuguese territory and a pioneer in the study of solar physics in Portugal.[40] He was also the first Portuguese scientist – astronomer or otherwise – to refer to the general theory of relativity in a paper published in the journal *O Instituto* in 1917. Having become aware of Einstein's results through a recent paper published by the American anti-relativist T. J. J. See,[41] he announced that the new theory provided an explanation for the anomalous advance of the perihelion of Mercury, and predicted the bending of light rays passing the Sun at grazing incidence.[42] But he objected to the theory on physical grounds. He proposed his own interpretation of the physical origins of gravitational attraction, based on radiation effects not on the geometrical characteristics of space–time. A regular participant in international conferences in Europe and the United States, together with the Portuguese mathematician Gomes Teixeira (1815–1933), in 1921 he founded the Portuguese Association for the Progress of Science.[43] During the Second Luso-Spanish Congress for the Progress of Science, which took place in Salamanca in 1923, he objected to special relativity for its lack of

37 OAL Archives. Ref. C-463 (1915–29): Correspondence M. Peres (OCR)/Oom (OAL), letter, Peres to Oom, 6 March 1919.

38 See list of publications in Melo e Simas, op. cit. (31).

39 As far as we know, Oom mentioned the expedition just once, in an appendix written for the third edition of the Portuguese translation of C. Flammarion's book *Les Merveilles célestes* (1865), written possibly between 1927 and 1930. OAL Archives. Ref. DD-554. Manuscript of the appendix together with notes on *Les Merveilles célestes*.

40 Costa Lobo, op. cit. (16), 20, 30.

41 T. J. J. See, 'Einstein's theory of gravitation', *Observatory* (1916), **39**, 511–12.

42 F. M. Costa Lobo, 'Explicação Física da Atracção Universal', *O Instituto* (1917), **64**, 611–13.

43 Associação Portuguesa para o Progresso das Sciencias /1st Congress (26 de Junho–1 Julho 1921) plenary sessions, Coimbra, 1922.

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empirical grounding and dubbed it a mathematical fancy, 'an interesting doctrine based on marvellous calculations but without applications to the physical world'.[44] Reducing it to a 'mathematical fashion', Costa Lobo declared dogmatically that the scientific community should concentrate on more fruitful research areas.

Ramos da Costa pursued research in solar physics and in the magnetic fields of the Sun and the Earth, and as we mentioned previously was simultaneously involved in the establishment and improvement of the Time Service in Lisbon's harbour. His astronomical activities, especially the former, might have profited from his participation in the 1919 expedition. Interestingly, after the expedition he endorsed relativity, wrote about it and became a successful popularizer.

The 1919 expedition to Principe

Einstein's steps to general relativity and its predictions have been well surveyed in the literature. With respect to the analysis of Eddington's expedition, historians of science have assessed the accuracy of its results and its impact on the acceptance of general relativity among the scientific community and the public at large, and the rise in popularity of Einstein as a public figure.[45] Even the religious motivations for Eddington's expedition and the ways such an enterprise fitted the pattern of cooperation of British Quakers during wartime have recently been discussed.[46] Before addressing the preparation and implementation of the expedition as well as the reactions of the Portuguese astronomical community, we briefly recall the intricate astronomical network of individual interactions that made Eddington sensitive to general relativity when the British response to the theory was far from enthusiastic, so that he so readily became involved in the preparations for the 1919 expedition at Dyson's request.[47]

This network involved very few astronomers. One was the German mathematician-turned-astronomer Erwin Finlay Freundlich, an early advocate of relativity and an active correspondent with Einstein, who discussed with Einstein alternative methods to check the light-bending hypothesis outside total solar eclipses, suggesting daylight solar photography or, alternatively, using the deviation of light rays bordering Jupiter's

44 F. M. Costa Lobo, 'La Structure de L'Univers', *O Instituto* (1923), **70**, 479–92.

45 J. Earman and C. Glymour, 'Relativity and eclipses: the British expeditions of 1919 and their predecessors', *Historical Studies in the Physical Sciences* (1980), **11**, 49–85; H. Collins and T. Pinch, *The Golem: What Everyone Should Know about Science*, Cambridge, 1993; P. Coles, 'Einstein, Eddington and 1919 Eclipse', e-print astro-ph/0102462 (2001); S. G. Brush, 'Prediction and theory evaluation: the case of light bending', *Science* (1989), **246**, 1124–9; *idem*, 'Why was relativity accepted?', *Physics in Perspective* (1999), **1**, 184–214; A. Warwick, 'Through the convex looking glass: A. S. Eddington and the Cambridge reception of Einstein's General Theory of Relativity', in *idem*, *Masters of Theory: Cambridge and the Rise of Mathematical Physics*, Chicago, 2003, 443–500.

46 M. Stanley, '"An expedition to heal the wounds of war": the 1919 eclipse and Eddington as Quaker adventurer', *Isis* (2003), **94**, 57–89; *idem*, *Practical Mystic: Religion, Science, and A. S. Eddington*, Chicago, 2007.

47 Of special help were Crelinsten, op. cit. (7), Part II; Earman and Glymour, op. cit. (45); Warwick, 'Through the convex looking glass', op. cit. (45); J. Stachel, 'Eddington and Einstein', in *idem*, *Einstein from B to Z*, New York, 2002, 453–75; and K. Hentschel, *Einstein Tower*: *An Intertexture of Dynamic Construction, Relativity Theory, and Astronomy*, Stanford, 1997.

surface. Another was the American astronomer Charles Dillon Perrine, who had been unsuccessfully involved in the search for the hypothetical planet Vulcan whose existence had been suggested by Leverrier to account for the anomalous behaviour of Mercury. Through Freundlich's acquaintance, Perrine had been interested in the astronomical implications of relativity since 1911. A third astronomer was the Dutchman Willem de Sitter, who worked out some astronomical consequences of the principle of relativity that Einstein had at the time used solely in the prediction of the gravitational red shift and light-bending. In this way he explained that perihelia motions were of the order predicted by Seeliger's hypothesis of a material dust ring.[48]

Eddington accidentally encountered Perrine during observations of the total solar eclipse of 10 October 1912 in Passo Quatro, Minas Gerais, Brazil.[49] Together with Freundlich, Perrine organized this expedition to test Einstein's light-bending prediction, becoming in this way actively involved in the astronomical consequences of a physical theory which promised to explain the behaviour of Mercury.[50] While the project failed due to bad weather conditions, one may conjecture that Einstein's 1911 results and the astronomical consequences of relativity theory were discussed by Perrine and Eddington, then in post at Greenwich Observatory.[51] Not long thereafter, in 1915, when Einstein finally arrived at his generally covariant gravitational field equations,[52] Eddington published several papers on relativity.[53] By the end of 1916 Eddington felt ready to present Einstein's results as explained in de Sitter's paper to the audience of the meeting of the British Association for the Advancement of Science held at Newcastle in early December.[54] Two years later in 1918 he published his *Report on the Relativity Theory of Gravitation*.[55]

When contacts between the Royal Astronomical Society and the OAL began at the end of 1918, Portugal was going through a difficult period. Having become a republican state in 1910, the country was then suffering several political, economic and financial crises, which converged into the brief dictatorial government of Sidónio Pais and the rightist wing of the Republican Party, the fight against monarchical insurrections and

48 W. de Sitter, 'On the bearing of the principle of relativity on gravitational astronomy', *Monthly Notices of the Royal Astronomical Society* (1911), **77**, 388–415.

49 A. S. Eddington, 'The Greenwich eclipse expedition to Brazil', *Observatory* (1913), **36**, 62–5; A. S. Eddington and C. Davidson, 'Total eclipse of the Sun, 10 October 1912. Report on an expedition to Passa Quatro, Minas Geraes, Brazil', *Monthly Notices of the Royal Astronomical Society* (1912–13), **73**, 386–90.

50 C. Perrine, 'Contribution to the history of attempts to test the theory of relativity by means of astronomical observations', *Astronomische Nachrichten* (1923), **219**, 281–4.

51 J. Eisenstaedt and A. A. Passos Videira, 'A relatividade geral verificada: o eclipse de Sobral de 29/05/1919', in Moreira and Videira, op. cit. (4), 90; Warwick, 'Through the convex looking glass', op. cit. (45), 452; Stachel, 'Eddington and Einstein', op. cit. (47), 454.

52 A. Einstein, 'Zur allgemeinen Relativitätstheorie', *Sitzungsberichte der Preussischen Akademie der Wissenschaften zu Berlin* (1915), **2**, 778–86, 799–801; *idem*, 'Die Grundlagen der allgemeinen Relativitätstheorie', *Annalen der Physik* (1916), **49**, 769–822.

53 A. S. Eddington, 'Some problems of astronomy. XIX. Gravitation', *Monthly Notices of the Royal Astronomical Society* (1915), **38**, 93; *idem*, 'Gravitation', *Observatory* (1915), **38**, 93–8.

54 Most probably this talk developed into A. S. Eddington, 'Gravitation and the principle of relativity', *Nature* (1916), **98**, 328–30.

55 A. S. Eddington, *Report on the Relativity Theory of Gravitation for the Physical Society of London*, London, 1918.

involvement in the Great War. With the murder of Pais, a period of confrontation between advocates of the Republican regime and the monarchy sharpened, giving way to a revolution which reinstalled the monarchy for a brief month at the beginning of 1919. The political aftermath of these events is discussed later in this paper.

The Portuguese contribution to the expedition was mainly logistical, involving ship reservations, arrangements with the Portuguese authorities at Principe and information on its natural resources and manpower that would eventually be of assistance during the travellers' stay.[56] The first letter written by Eddington, on Armistice Day, 11 November 1918, informed the observatory's director Campos Rodrigues about the decision to organize the expedition and asked for help in finding transport to the island, a place to stay and local help in the preparations for the 'big day'. Eddington also referred to information already provided by Captain Ernesto de Vasconcelos, president of the Sociedade de Geografia de Lisboa (Geographical Society of Lisbon), to Arthur Hinks concerning the geographical and meteorological conditions on the island.[57] Campos Rodrigues soon contacted the local authorities and specifically the Colonial Centre (the representative of the Colonial Agricultural Society) in an exchange of letters covering the period from 28 November 1918 to 18 March 1919. The reply to Rodrigues's first letter informed him that the plantation landowner Jerónimo Carneiro would offer subsistence as well as material and human support for the British astronomers.[58] Eddington also wrote to the vice-director specifically asking for help in ship reservations and voicing concern over the extra difficulties associated with the unstable political situation following the revolution which reinstalled the monarchy for a brief period in early 1919: 'We find that all sailings of boats to Lisbon have been cancelled for the present – I suppose owing to the revolution. I trust that you and the observatory are unharmed.'[59] In reply Oom referred to the possibility that Peres, director of the observatory in Mozambique, might join the expedition: 'besides being familiar with English, [he] may otherwise make things easy for you there'.[60] Contacts between the OAL and the Companhia Nacional de Navegação (CNN – National Navigational Company) secured places for the British astronomers on the ship *Portugal* and exemption from customs inspection.[61]

On 8 March 1919 the two expeditions set sail from Liverpool on board HMS *Anselm* and they headed towards the Portuguese island of Madeira. On their way they stopped at Lisbon on 12 March, and the two teams visited the observatory where they signed the guest book (Figure 1).[62]

56 OAL Archives. Ref. C-240 (1918/1919): Correspondence Eddington/OAL.

57 A. R. Hinks, 'Geographical conditions for the observation of the total solar eclipse, 1919 May 28–29', *Observatory* (1917), **78**, 79–82.

58 OAL Archives. Ref. C-240 (1918/19), letter, Campos Rodrigues to the director of the Colonial Centre, 28 November 1918, 5; letter, M. C. Rego (president of the Colonial Centre) to Campos Rodrigues, 16 December 1918.

59 OAL Archives. Ref. C-240 (1918/19), letter, Eddington to Oom, 8 February 1919.

60 OAL Archives. Ref. C-240 (1918/19), letter, Oom to Eddington, 13 February 1919.

61 OAL Archives. Ref. C-240 (1918/19), letter, Campos Rodrigues to Commander A. J. Pinto Basto (CNN), 13 February 1919.

62 OAL Archives (DD-455), Guest Book.

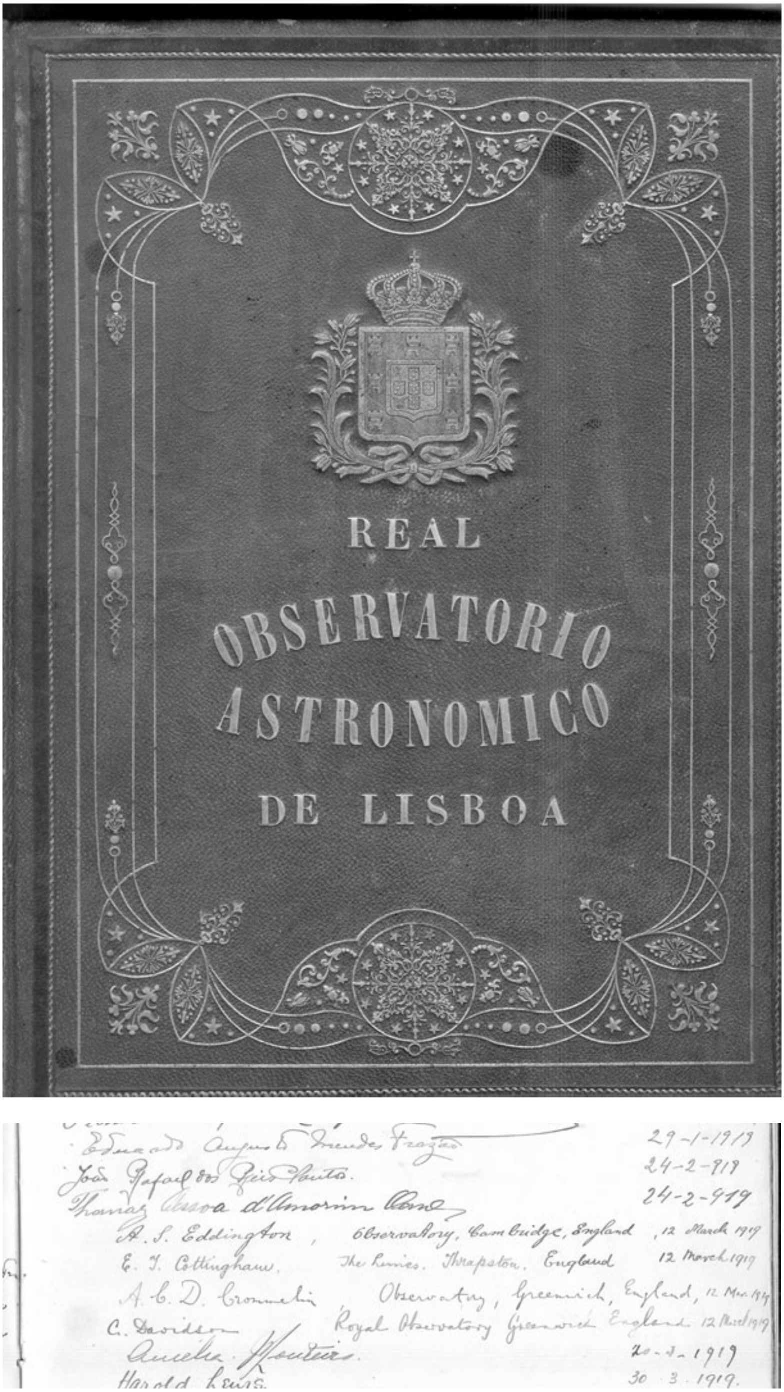

Figure 1. Guest Book and the astronomer's signatures (courtesy of the OAL).

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Two days later they arrived in Madeira. While in Funchal, Eddington received the letter of introduction written by the officials at the Colonial Centre to the plantation landowner Jerónimo Carneiro.[63]

In Madeira the expeditionary groups split. Crommelin and Davidson's team continued their journey and arrived at Pará, Brazil, on 23 March.[64] They were joined by a Brazilian team headed by Morize, the astronomer and director of the Observatory of Rio de Janeiro, and supported by the Brazilian government as a deliberate contribution to this international project. Unsurprisingly the Brazilian team did not take part in the observations of the deflection of light, but used the opportunity to make astrophysical observations, as was then common astronomical practice. They observed the overall shape of the solar corona, the outermost part of a star's atmosphere, and used spectroscopic methods to analyse its chemical composition. They found evidence of hydrogen, helium and a hypothetical element named 'coronium'.[65] According to Morize's diary they rarely interacted with the British team.[66] In fact, the response of the Brazilian scientific community to relativity was still to come. It followed Einstein's 1925 South American tour.[67] Morize had been asked by the Carnegie Institution's Louis Bauer to make electric and magnetic measurements but was unable to carry them out. For this reason a team of American observers from Carnegie joined them to take care of the measurements. Oom had also been contacted by F. Brown, Bauer's collaborator, to help with ship reservations to Principe but in the end opted to make electric and magnetic measurements at Duala in Cameroon.[68]

Eddington's team stayed in Funchal for several weeks. On 9 April they boarded the *Portugal* and arrived at the port of Santo António in Principe on 23 April.[69] Upon their arrival the astronomers surveyed the island to select the most appropriate observational site and settled for the Sundy plantation, owned by their host, Carneiro. This plantation was in the west of the island, a region less prone to cloudiness during the month of May and thus more promising of observational success. Their luggage was transported to Sundy on 28 April using the private rails of the plantation. The sole letter from Eddington to the OAL reporting on Carneiro's hospitality and the island's beauty dates from this period.[70] However, in more personal correspondence to his family, Eddington depicted the inhospitable natural conditions of daily life on the island. Being cut off from the world and Europe did not help. He did not even know if peace had been signed.[71] The astronomers stayed in Santo António from 6 to 13 May,

63 OAL Archives. Ref. C-240 (1918/19), letter, Colonial Centre to Campos Rodrigues, 18 March 1919.

64 A. C. Crommelin, 'The eclipse expedition to Sobral', *Observatory* (1919), **42**, 368–71.

65 R. Mourão, *Einstein de Sobral para o Mundo*, Sobral, 2003, which includes Morize's diary.

66 Mourão, op. cit. (65), 119–45.

67 Tolmasquin, op. cit. (2); Mourão op. cit. (65).

68 OAL Archives. Ref. C-240 (1918/19): Correspondence Brown /OAL, letter, Oom to Brown, 13 March 1919; letter, Brown to Oom, 24 April 1919. See *Nature* (1919), **103**, 131–2.

69 Dyson, Eddington and Davidson, op. cit. (1). The paper includes a form of diary of the trip that precedes the description of the preparatory work and the analysis of the data.

70 OAL Archives. Ref. C-240 (1918/1919), letter, Eddington to Oom, 4 May 1919.

71 Letters to S. A. Eddington and W. Eddington, 29 April, 21 June, 5 May, in Stanley, 'An expedition to heal the wounds of war', op. cit. (46), 75.

and returned to the plantation on 16 May finally to concentrate on the preparation work. The fierce humidity covering the island prevented an earlier attempt. By 10 May the 'gravana' had settled, a typical meteorological configuration characterized by south and south-east winds blowing from the Gulf of Guinea, usually lasting from fifteen to twenty-one days. The gravana was accompanied by thick haziness that grew during the following days. On the day of the eclipse the rain started in the morning and a storm, unusual for this time of year, swept the region. A cloudy and menacing sky accompanied the astronomers throughout the eclipse and only during its last third did cloudiness diminish considerably. Later Eddington recalled the excitement of the observations:

> Our shadow-box takes up all our attention. There is a marvelous spectacle above, and, as the photographs afterwards revealed, a wonderful prominence-flame is poised a hundred thousand miles above the surface of the sun. We have no time to snatch a glance at it. We are conscious only of the weird half-light of the landscape and the hush of nature, broken by the calls of the observers, and the beat of the metronome ticking out the 302 seconds of totality.[72]

The next phase was no less exciting. When the team began developing the pictures taken during the eclipse they were confronted with a difficult situation. Of the sixteen pictures taken, only six showed any stars at all, and only two of these six revealed five stars, the minimum necessary to get an acceptable result. No wonder Eddington sent a telegram to Dyson simply reporting 'through clouds, hopeful'.

The results of the twin expeditions ($1.6'' \pm 0.3$ for Principe; $1.98'' \pm 0.12$ for Sobral) were compatible with Einstein's prediction of a $1.75''$ deflection value.[73] They were presented by Eddington, Dyson and Davidson at the joint meeting of the Royal Society of London and the Royal Astronomical Society on 6 November 1919 and were followed by the verdict of the patriarch J. J. Thomson who presided over the session:

> If it is sustained that Einstein's reasoning holds good – and it has survived two very severe tests in connection with the perihelion of Mercury and the present eclipse, – then it is the result of one of the highest achievements of human thought.[74]

Much historical debate has surrounded the evaluation of the criteria used by Eddington in analysing the observational results and their conclusions.[75] Although this paper is not centrally concerned with this topic, one should bear in mind that eclipse observations were then made at the limits of available technology. Just four months before, on 11 July 1919, a meeting of the Royal Astronomical Society chaired by William Wallace Campbell had gathered in London to discuss the results of former eclipse expeditions.[76] Following this, other eclipses were checked for extra confirmations of light-bending, with much expectation surrounding the 1922 eclipse. Only

72 A. Eddington, *Space, Time and Gravitation: An Outline of the General Relativity Theory*, New York, 1959 (first edn 1920), 115.

73 Dyson, Eddington and Davidson, op. cit. (1).

74 J. J. Thomson, 'Joint eclipse meeting of the Royal Society and the Royal Astronomical Society', *Observatory* (1919), **42**, 389–98, 394.

75 Stanley, opera cit. (46) has recently argued in favour of Eddington's criteria and their consistency, opposing the current view that Eddington fudged his results and therefore practised 'bad science'. A similar argument is put forward in Coles, op. cit. (45). Contrary opinions were previously voiced in Earman and Glymour, op. cit. (45); and Collins and Pinch, op. cit. (45).

76 Crelinsten, op. cit. (7), 76–84, 131–40.

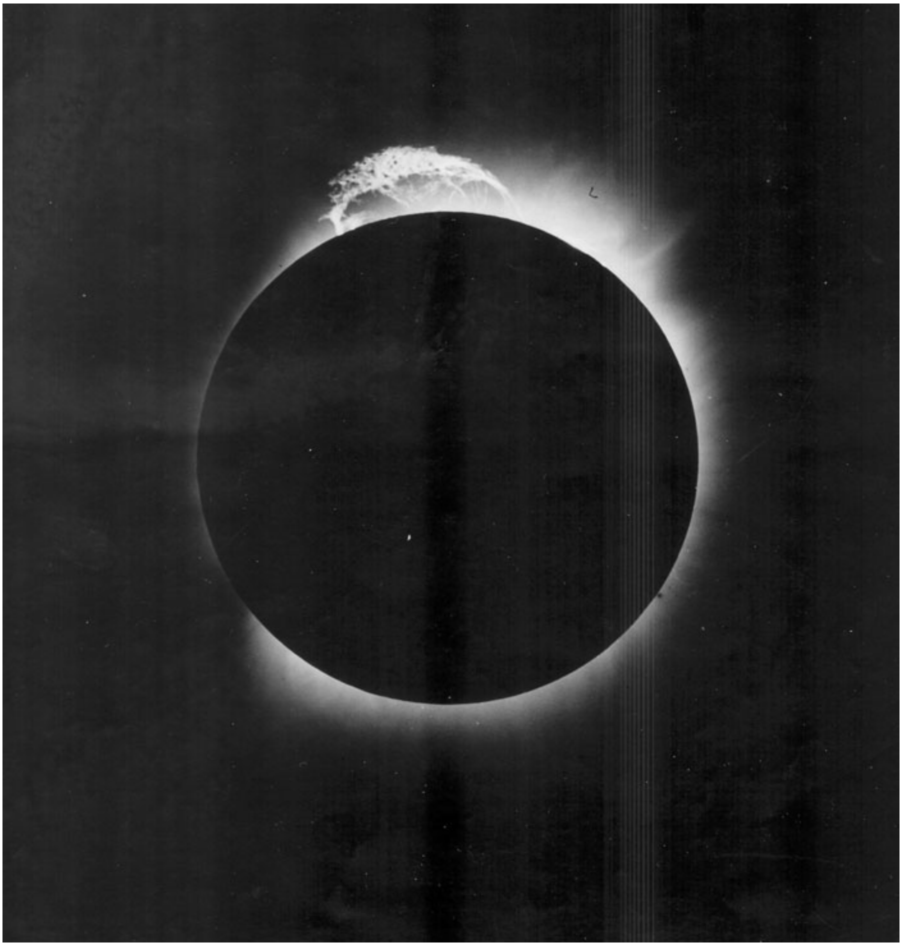

Figure 2. Solar prominence – Principe, 29 May 1919, 2 hours 13 minutes 28 seconds GMT, exposure 10 seconds (through cloud) (courtesy of the OAL).

after the 1960s, with Irwin I. Shapiro's time-delay techniques and the recourse to radio sources (which circumvented the dependence on solar eclipses), was it possible sufficiently to reduce observational error such that the deflection of light rays was considered proven beyond any reasonable doubt.

After the expedition in August 1919 the British astronomers got in touch one last time with the OAL to thank the local authorities, specifically the National Agricultural Society and the observatory, and to send them the 'paper enlargements' of the plates taken on 29 May.[77] This letter explicitly mentioned a photograph that captured a spectacular solar prominence (Figure 2).[78]

77 OAL Archives. Ref. C-240 (1918/19), letter, Eddington to Campos Rodrigues, 3 August 1919, 43.

78 OAL Archives. Ref. C-240 (1918/19), draft letter, n.d., 44. In the draft letter by Campos Rodrigues to Eddington, the Portuguese director acknowledges the reception of the enlargements of the paper.

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No news of the expedition was carried by Portuguese newspapers, periodicals or magazines in the immediately ensuing months save for a brief note entitled 'Light has weight' published on 15 November 1919 by the daily generalist newspaper *O Século* (The Century). It reported on the joint meeting of 6 November but no mention was made of the observations stemming from Principe or of Einstein's name.[79]

Two months later, in January 1920, a one-and-half-page article was published in the Jesuit journal *Brotéria*, then devoted to the popularization of science, reporting on the eclipse expedition to Brazil, but not mentioning the twin expedition organized in Portuguese territory. Entitled 'The total solar eclipse of 29 May 1919, in Brazil', it enumerated the three possible results of the deflection measurements (no result, a 0.875″ deflection, or a 1.75″ deflection) and stressed that the aim of the expedition was to study 'the deflection of light rays through the ether on their way towards Earth'. The author concluded,

> The reason astronomers are paying attention to this system [Einstein's theory] has to do with its explanation of an anomaly which has long puzzled them: the major axis of the elliptical orbit of Mercury advances towards the Sun with a movement considerably larger than the one predicted by the older theory; this movement is in accordance with the one predicted by Einstein's theory.[80]

Besides referring to the ether while explaining Einstein's theory, the author gave special emphasis to the explanation of the advance of the perihelion of Mercury both as a confirmation of the theory and as an extra stimulus for astronomers to test another prediction of the theory.[81]

Portuguese astronomers and relativity

Preceded by a long period of gestation, the inauguration of the Republic in 1910 brought the hope of a new society built on democratic, socialist-oriented, anti-clerical, nationalist and colonialist values.[82] Ideologically the Republic counted on the support of many intellectuals, including scientists who praised the gospel of positivism and endorsed scientism, mostly as an initial reaction against a society formerly dominated by religion and subsequently as a more or less explicitly articulated philosophical project.

During the First Republic, which lasted until 1926, the educational system underwent drastic changes ranging from primary to university level and the education of women.[83] The hegemony of the University of Coimbra ended in 1911 with the creation of the universities of Lisbon and of Porto. Their schools of sciences incorporated the former

79 'A luz pesa' (Light has weight), *O Século*, 15 November 1919, section 'Descobertas científicas' (Scientific discoveries).

80 C. Torrend, 'O eclipse total de 29 de Maio de 1919, no Brasil', *Brotéria* (January 1920), 40–1.

81 Brush, opera cit. (45).

82 Although some of the former characteristics are easily understood as a reaction to monarchical values, nationalism and colonialism were a response to the outcome of the Berlin Conference (1895) and the Portuguese response in securing its African colonies.

83 Rómulo de Carvalho, *História do Ensino desde a Fundação da Nacionalidade até ao fim do regime de Salazar-Caetano*, Lisboa, 1985.

polytechnic schools, created in the first half of the nineteenth century in the context of a liberal monarchy. Simultaneously, universities such as the Free University (Universidade Livre) and the Popular University were created to implement the ecumenical and democratic spirit of the First Republic, embodied in a project of 'education for all'. Addressed to all classes, including first and foremost the working class, they promoted conferences, courses and talks and became involved in a steady process of popularization of science.[84]

Portuguese astronomers' early response to relativity, which took place during the First Republic, was heavily dependent on their astronomical practice. Astronomers who belonged to the OAL or were in some way related to it generally responded positively to relativity, whereas Costa Lobo, who worked at the Observatory of Coimbra, reacted against it. The role of the astronomer F. Oom, successor to Campos Rodrigues as director of the OAL and whom Manuel Peres was to replace, is crucial in understanding the construction of a community of scientists around the OAL involving both astronomers and those using astronomy as an auxiliary. They were keen on networking in both national and international fora. Besides being involved in the many previously discussed astronomical missions, they kept up to date with recent advances by reading standard periodicals in the area, by attending meetings and through membership in commissions and societies.[85] These activities reinforced their research agenda and were crucial to furthering their sense of community both locally and internationally.

Oom became a mediator between astronomers associated with the OAL and those affiliated with colonial observatories, as well as those who performed fieldwork aimed at longitude determinations, used triangulation methods in geodesy work, or were associated with the Time Service. He also often tutored them in their initial training in positional astronomy. While he did not contribute to any publications on relativity, he was not neutral. When his colleagues got involved with the popularization of relativity, he acted to bind them together. He pressed Peres to publish his book on relativity, supervised the publication of the papers by Peres and Melo e Simas in the observatory's journal *Almanaque*, collaborated with Ramos da Costa in the time

84 Rogério Fernandes, *Uma experiência de formação para adultos na Primeira República. A Universidade Livre para a Educação Popular 1911–1917*, Lisboa, 1933. The Free University was founded in Lisbon in 1912 by Alexandre Ferreira. The Popular University started in 1911 in Porto and in 1919 in Lisbon. Among its teachers was the philosopher and mathematician Leonardo Coimbra, who was the first Portuguese to refer to special relativity in a journal article and in a book which was the dissertation prepared for his application for a teaching position in philosophy at the Faculty of Humanities of the University of Lisbon (Faculdade de Letras da Universidade de Lisboa). Leonardo Coimbra, *Criacionismo*, Porto, 1912. He was critical of positivism and endorsed idealist views, claiming that our knowledge of the natural world is guided by thought, not by our daily experience. He belonged to the Portuguese Republican Party after 1914 and was minister of public instruction twice, in 1919 and 1923.

85 Portuguese astronomers belonged to the following international associations: International Geodesic and Geophysics Commission, Portuguese–Spanish Association for the Progress of Science, International Astronomical Union, South African Association for the Progress of Science. Most probably, the OAL subscribed to fifty scientific periodicals in the period under consideration. Among them, the *Observatory*, the *Monthly Notices of the Royal Astronomical Society* and *Astronomische Nachrichten* were those most used as publication outlets for the astronomers of the OAL.

determination and dissemination that spurred his publications' ventures, and became a privileged interlocutor of Gago Coutinho about geodesic projects and in the discussion of relativity.

Melo e Simas and the popularization of relativity

Given the importance attributed by the Free University to the instruction of its students in 'their true role in the cosmos', it is no wonder that astronomy was rather popular among its lecture topics.[86] Melo e Simas inaugurated its lectures, delivering two on the theme beginning in 1913, one entitled 'Usefulness of astronomy. Greatness and magnificence of the universe. General idea on the distribution of worlds', and the other 'Eclipses of the sun and moon'.[87] It is suggestive that this first set of lectures was dedicated explicitly to analysing the 'utility' of physics, mathematics and chemistry, as well as discussion of the 'functions of science'. Alongside this positivist orientation, a concern for colonial questions, to which eight of twenty-nine lectures were devoted, revealed the importance of this topic in the social and political context of the First Republic.

The first class began with a section on 'Scientific instruction and positive education', where Melo e Simas stated that 'in science there are no personalities … In science things do not happen as in politics, in which the individual is everything and the idea is nothing'.[88] This intriguing statement may illuminate Melo e Simas's brief tenure in a post in the Ministry of Public Instruction ten years later. As one of his colleagues said, he 'was structurally an astronomer, an astronomer less by profession than by soul', and he went on to justify his transient engagement in politics. In politics he stubbornly behaved as a 'mathematician-politician', not as an 'artillery-politician', attempting to win people to his ideas by using demonstrative methods rather than by the power of 'grenades'. The colleague concluded that

> his comrades were sorry when he abandoned the Army for Astronomy; astronomers were sorry that he spent too many hours in politics instead of devoting them to observations and calculations; only politicians, I guess, were not sorry for his abandonment of politics.[89]

Much later, Melo e Simas delivered a set of thirteen lectures at the Free University on 'Relativity – notions and fundamentals', between 19 November 1922 and 27 May

86 On Melo e Simas see also A. Simões, 'Considerações históricas sobre ciência e sociedade: divórcio litigioso ou casamento de sucesso?', in *Encontro de Saberes. Três gerações de bolseiros da Gulbenkian* (ed. A. Tostões, E. R. Arantes de Oliveira, J. M. Pinto Paixão and P. Magalhães), Lisboa, 2006, 247–57.

87 Leaflet of the lessons of the Free University, Lessons 1 and 8, *Boletim Mensal* (Monthly Bulletin of the Free University), Lisboa, 1912.

88 M. S. Melo e Simas, *Usefulness of Astronomy. Greatness and Magnificence of the Universe. General Idea on the Distribution of Worlds*, Lisboa, 1913, 4. From this period in July 1912 there also dates an *éloge* of Poincaré by Melo e Simas read at the Academy of Sciences of Portugal. *Idem*, 'Poincaré e a sua obra', *Relatório dos trabalhos da Academia de Sciências de Portugal (1914–1915)* (1915), **2**, 17–19.

89 OAL Archives. Ref. DD-454. Undated and unsigned manuscript obituary. Its author was probably Manuel Peres, Melo e Simas's successor in the class of mathematics at the Academy of Sciences of Lisbon. Peres's opinion was also shared by the astronomer Pedro José da Cunha, former teacher of Melo e Simas at the Polytechnic School of Lisbon. Cunha, op. cit. (15), 20.

1923.[90] In a country in which people, mostly women, attended Mass on Sunday mornings, these lessons took place on Sundays and were well attended, according to newspaper reports.[91] In the spirit of Thomas Henry Huxley's lay sermons, the gospel of science was meant to reach out to laypeople. This is all the more revealing as the topics of the lectures were far from elementary, even if the lectures themselves were clear and well articulated, at least as far as can be gathered from their detailed summaries.[92] They were introduced sequentially, starting from the mathematical background of physics and moving on to elementary notions of classical physics, physical agents and components of matter, and the different space and time scales applicable in different regions of the universe. These topics were followed by a discussion of the ether's role, the Michelson–Morley experiment and the Lorentz and Fitzgerald hypotheses proposed to accommodate its results. This was presented as the prelude to relativity, from the 'predictions of Poincaré' to the 'intuition of Einstein'. A presentation of the theory of relativity followed, highlighting its novel concepts of space, time, simultaneity, mass and energy and space–time, as well as their mathematical underpinning. This led to a brief discussion of general relativity, its three predictions and the role of solar eclipses in proving the light-bending hypothesis. The emphasis on physical notions was complemented by philosophical considerations about the role and importance of science, scientific characteristics such as objectivity and abstraction from the real world, the role of observations and experiments, scientific time patterns from evolution to revolution, and the relations of science and art. A reference to the public impact of relativity was indicated as a motivation for principal attempts at popularization. Melo e Simas felt comfortable with this trend, and in fact had long been an active participant in popularization of scientific activities.

At the start of the century he had already contributed several articles on the relations between astronomy and society to the Azorean literary newspaper *A Folha* (The Leaf).[93] In one he addressed the role of women in science, and specifically in astronomy:

> Scientific outcomes measure the degree of civilization of a country. In France, Russia and especially in England and in the United States, women rival men as contributors to scientific progress; among us, only recently have there been attempts at circumventing routine, opening higher education to Portuguese women, whose qualities of intelligence, perseverance and energy are constantly proving not to be inferior to those of any other women.[94]

90 OAL Archives. Folder on Melo e Simas. List of titles of lectures on relativity delivered by Melo e Simas at the Free University, from 19 November 1922 to 27 May 1923.

91 Cunha, op. cit. (15).

92 It has so far proved impossible to find the manuscripts of the lectures. According to their titles, the 'introductory survey' was succeeded by the 'spirit of mathematical reasoning', 'the spirit of geometrical reasoning', 'the spirit of classical mechanics', 'physical agents', 'the constitution of matter', 'the relativism (scales) of space', 'preliminaries to relativity', 'special relativity', 'the mechanics of relativity', 'the four dimensions of the Universe' and, finally, 'the spirit of general relativity'.

93 M. S. Melo e Simas, 'Astrologia e Astronomia', *A Folha. Jornal Literário, noticioso e comercial* (1º Ano, nº 17, 25 Janeiro 1903), 1; *idem*, 'A mulher na astronomia', *A Folha. Jornal Literário, noticioso e comercial, localista e independente* (2º Ano, nº 60, 22 Novembro 1903), 1.

94 Melo e Simas, 'A mulher na astronomia', op. cit. (93).

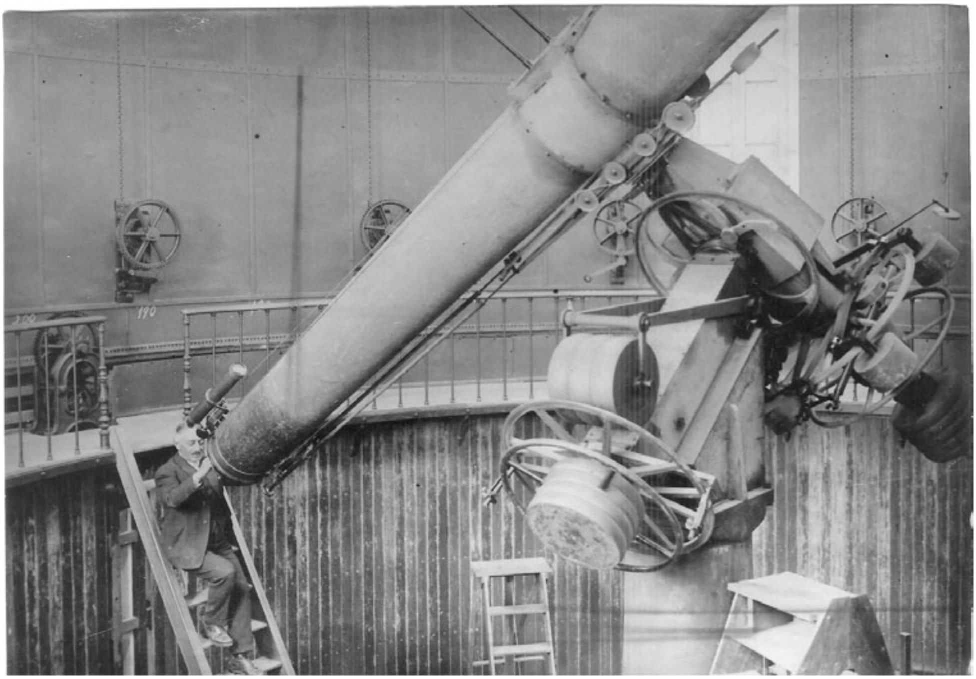

Figure 3. Melo e Simas at the Great Equatorial (courtesy of the OAL).

Some months before the start of lectures at the Free University in July 1922, Melo e Simas published a paper in the *Almanaque*, the observatory's popularization journal, in which he made observations on the relationship between astronomy and physics in the context of the results of a further expedition soon to test the light-bending prediction in Australia:

> At this moment the name of a German attracts our appreciation as well as the admiration or curiosity of the learned and non-learned world … *[I]t is certain that Astronomy is one of the sciences which can profit the most from the theory of Relativity, giving back, in exchange, the best of confirmations* … A ray of light changes direction in the proximity of a gravitational field. That is, instead of travelling in a rectilinear path, light describes curved trajectories depending on the gravitational fields it traverses. This consequence was verified on the occasion of the solar eclipse of 29 May 1919, and expeditions are being prepared to confirm it during the next solar eclipse of September 1922.[95]

Besides his judgement of changes in disciplinary boundaries because of the emergence of relativity and their implications for the science of astronomy, and unlike many of his fellows who joined him in scientific popularization, Melo e Simas was the only astronomer to try to accommodate the new theory within his scientific practice (Figure 3). In 1924 Melo e Simas presented a communication to the Academy of Sciences of

95 M. S. Melo e Simas, 'A teoria de relatividade', *Almanaques de 1924* (OAL, 1922), 43–57, 43, 44, 56, italics ours. On the occasion of the 1922 solar eclipse Melo e Simas also gives an interview for the newspaper *O Século* (21 November, 5) in which he refers to Leonardo Coimbra.

Lisbon to which he also belonged. He explained how, following a request from the *Astronomische Nachrichten*, he had observed the occultation of a star by Jupiter in the Observatory of Lisbon on the night of 7 May 1923, and additionally used it to test the light-bending prediction:

> The process consisted in determining the relative position of the two bodies some minutes before and after occultation, in such a way that starting from the position of one it was possible to calculate the position of the other at a certain specified moment. In this way one obtains not only a series of verifications, difficult to obtain by other means, but also the means to deduce the effects of any influence in the occultation itself, either coming from light radiation or from the planet's atmosphere or from not taking into consideration the calculations of the theory of relativity.[96]

With these words he explains the usefulness of an occultation, which occurs when one celestial body is hidden by another. He simultaneously elucidates how this observation could be used to test general relativity. Recognizing that the deflection of light by Jupiter should change the apparent position of the star by about 0.02″ according to general relativity, a negligible value to be measured by any rigorous method, Melo e Simas turned his attention to the relativistic time delay of the occultation's duration, instead of measuring the light deflection directly. But he considered that although the results revealed a 'certain tendency pointing towards relativity theory', no conclusion could be drawn due to the occurrence of other effects, such as the refraction of light in the planet's atmosphere which produced deviations in the same direction. It should be stressed that this attempt was probably independent, and certainly different, from Freundlich's method, which involved taking photographs of stars as they faded away behind Jupiter and comparing their positions when Jupiter occupied another region of the night's sky. In this way Melo e Simas became the sole Portuguese astronomer to attempt to prove Einstein right.[97]

Manuel Peres, time determination and the book nobody read

While the international community was preparing for the 1922 expedition to observe another solar eclipse and Melo e Simas was calling attention to the growing importance of astronomy in the new physical context opened up by the predictions of relativity, Manuel Peres was thinking along the same lines. In July 1922 he organized the Twentieth Congress of the South African Association for the Progress of Science in Lourenço Marques, and chaired the first section on Astronomy and Mathematics. In his presidential address he also discussed the role of astronomy in science and voiced concerns similar to those of Melo e Simas. Both reacted in this way to the 1922 expedition. Peres gave a prominent place to the recent explanation of the irregularities

96 M. S. Melo e Simas, 'Ocultação de uma estrela por Júpiter', op. cit. (10), 115.

97 While we were unable to explain fully Melo e Simas's involvement in Jupiter's observational project to test general relativity, we point to one possible correlation. At the time of Jupiter's observations, Perrine had just written a paper for *Astronomische Nachrichten*, a journal in which Lisbon astronomers published on a regular basis, reviewing the different methods to test relativity by astronomical means. See Perrine, op. cit. (50).

in the motion of Mercury's perihelion offered by relativity and went on to predict that this theory would soon replace Newtonian mechanics.[98] Furthermore, he stressed that the credibility of Einstein's relativity theory depended, then as in the future, on the confirmatory role of astronomical observations, predicting the consolidation of the strong ties linking astronomy and physics: 'As you know, the main confirmation of Einstein's viewpoints depends on astronomical observations … Therefore in its development, physics arrives at a crossroads, and expects astronomy to point out which of two directions should be chosen.'[99]

Probably encouraged by Oom, Peres was then writing a book in which he discussed the special as well as the general theory of relativity and analysed the consequences of the general theory of relativity as well as its confirmation. But in the meantime Ramos da Costa's book, to be discussed in the next section, was published, and Peres became unsure about the timing of his own work.[100] Despite Oom's continuing insistence, the book was never published, although it was very likely finished. By June 1923 Peres replied to Oom, who had pressed him again to publish: 'So, you insist on the idea that it is still worthwhile to publish the book on relativity? I find it banal, but your persistence is unsettling. I will try my best.'[101] The analysis of its few extant pages leads to a possible correlation of his comments on special relativity with his practice as a positional astronomer in charge of time determination and dissemination in Mozambique. Peres contrasted Newtonian absolute time, which he dubbed 'metaphysical time', and the time measured by clocks, which he called 'physical time', the topic of relativistic mechanics. He seemed to be influenced by Poincaré's conventionalism, in the sense that this philosophical system enabled one to solve some questions directly related to time measurement:

> The measurement of time involves difficulties which we can solve only by recourse to conventions … The fact that two different methods [measurement of time by the pendulum clock or by the Earth's rotation] lead to the same result indicates that they are independent from the conventions in which they are based. But the truth is that the two methods make claims which do not entirely agree. In order for them to agree, it is necessary to introduce more conventions …[102]

These were old concerns of his. Back in 1916, when already director of the OCR, he had published a paper titled 'Determination by wireless telegraphy of longitude difference between points which are not in the field of action of the same emitting station'.[103] At a time when longitude determinations were often used in hydrography

98 OAL Archives. Ref. C-463 (1915–1929): Correspondence M. Peres (OCR)/Oom (OAL); M. Peres Júnior, 'The role of astronomy in the development of science', *South African Journal of Science* (1922), **19**, 32–41. Portuguese translation: *O papel da astronomia no desenvolvimento da ciência*, Lisboa, 1923.

99 OAL Archives. Ref. C-463 (1915–1929): Correspondence M. Peres (OCR)/Oom (OAL); Peres Júnior, 'The role of astronomy', op. cit. (98), 41.

100 OAL Archives. Ref. C-463 (1915–1929): Correspondence M. Peres (OCR)/Oom (OAL), letter, M. Peres to F. Oom, 18 February 1922.

101 OAL Archives. Ref. C-463 (1915–1929): Correspondence M. Peres (OCR)/Oom (OAL), letter, M. Peres to F. Oom, 30 June 1923.

102 OAL Archives. Ref. DD-602. Peres's manuscript pages 'Geometry and experience'.

103 M. Peres, 'Determinação pela telegrafia sem fios, da diferença de longitudes de dois pontos que não estão no campo de acção da mesma estação emissora', *Arquivos da Universidade de Lisboa* (1916), 1–3.

and geodesy, and especially in geographic missions to establish borders in colonial territories, Peres described new and very precise ways to calculate longitudes using the modern technology of radio signals. He contrasted two methods – the method of coincidences and the method of crossing signals:

> In the determination of longitude by wireless telegraphy, when great accuracy is required, the radiotelegraphic station broadcasts a series of equally spaced signals, which are received by the observers at the two places for which the longitude difference is to be calculated. By the method of coincidences, these observers determine the time marked by their clocks upon any signal's occurrence. The time difference, corrected by the states of their clocks, represents the longitude difference. If the distance between each place and the radio station is large, the time spent by Hertzian waves to travel this distance may be non-negligible, despite the fact that they travel at the speed of light. The error involved may be eliminated with another longitude determination, using another radio station for which the difference will have the same magnitude but opposite sign.[104]

He went on to explain how to make longitude determinations when the two observers were not in the field of influence of the same radio station. To circumvent the problem, a third observer with a chronometer and a receiver should be located in a place where the fields interfered. As has been pointed out, for Peres these were not merely theoretical considerations. They were considerations spurred by his activity as director of a colonial observatory, the first in Portugal to use this innovative method of signal transmission.

Ramos da Costa, the Time Service and two books on relativity

It was once again the astronomical practice of Ramos da Costa as a naval officer in charge of time measurements and the transmission of standard time in Lisbon harbour that set him on the path to special relativity. In 1921, after many years involved in this task, Ramos da Costa published a book titled *Practical Treatise on Chronometry*, including a chapter on 'The measurement of time' in which he described in detail the various instruments used for time determinations and discussed how to synchronize clocks on board moving ships by means of telegraphic signals broadcast from the Eiffel Tower.[105] That same year he wrote another book, *The Theory of Relativity* (1921), and two years later *Space, Matter, Time or the Einsteinian Trilogy* (1923).[106]

From the outset Ramos da Costa revealed his concern to contribute to the popularization of relativity, pointing out that relativity was based in ingenious mathematical and philosophical notions of interest 'not only to the mathematician and the philosopher but also to the astronomer and the physicist'.[107] He understood that different communities of scientists reacted differently to relativity and that appropriate arguments should be used accordingly. He adopted Poincaré's principle of relativity that still preserved the existence of the ether[108] devoid of mechanical properties.[109] While he

104 Peres, op. cit. (103), 2.

105 A. Ramos da Costa, *Tratado Prático de Cronometria*, Lisboa, 1921.

106 A. Ramos da Costa, *A Teoria da Relatividade*, Lisboa, 1921; *idem*, *Espaço, Matéria, Tempo ou a Trilogia Einsteiniana*, Lisboa, 1923.

107 Costa, *A Teoria da Relatividade*, op. cit. (106), pp. iii–iv.

108 Costa, *A Teoria da Relatividade*, op. cit. (106), 21.

109 Costa, *A Teoria da Relatividade*, op. cit. (106), 57.

accepted that Michelson and Morley's experiment proved that absolute simultaneity depended on the instantaneous propagation of light, the contraction hypothesis put forward by Lorentz to account for its negative result meant that the mysterious contraction could just be explained as an apparent, not a real, effect.[110] He defined time in the following operational way: 'On the earth's surface, time is transmitted by wireless telegraphy in such a way that time corresponds to the passage of a Hertzian signal through the stations whose clocks we wish to synchronize.'[111] He went on to give examples of the simultaneity of two distant events, pointing to the differences arising from the fact that events were described in moving reference frames, such as ships, or in reference frames at rest, in such a way that 'two events which are simultaneous in the first reference frame are not simultaneous in the second; that is, two events may be simultaneous in one reference frame but not in another'.[112] There is a close analogy between the way Ramos da Costa described how to synchronize moving clocks and Poincaré's metaphor of the longitude measurer, with the difference that he chose ships instead of trains.

Ramos da Costa objected to those who misinterpreted relativity by considering that it had 'demolished Newtonian principles'. He claimed that instead of replacing it, the new theory modified and extended Newtonian physics. Following Poincaré, he held that the new theory should be judged in terms of its convenience: 'there is a time when the criterion of convenience is so strong that it is in practice equivalent to logical certainty'. To reach as many people as possible he avoided mathematical formulae and opted for clarity instead of elegance, whenever both could not coexist. Paraphrasing Poincaré, he concluded that 'elegance is the attribute of tailors and shoemakers'.[113] He certainly succeeded in his endeavour, offering an up-to-date, succinct, clear and persuasive account.

In the second book, he analysed the background to the emergence of special relativity, considering Michelson and Morley's experiment and the meaning of Lorentz's proposals, but never referring to those of Poincaré. He stressed that Michelson and Morley's experiment proved the impossibility of instantaneous action at a distance and that the notion of absolute simultaneity was dependent on belief in instantaneous propagation. He discussed the notions of space and time, Minkowski's four-dimensional space–time, and the equivalence of mass and energy, as well as the equivalence of inertial and gravitational mass and the geometrical interpretation of gravitation put forward by general relativity. For him, the theory of relativity was an ineluctable consequence of the evolution of science, backed by the discovery of microscopic particles travelling at speeds close to the speed of light. He focused on the need to accommodate these novel facts into a new science of mechanics. He paid particular attention to the empirical tests of general relativity, namely to the measurement of light-bending during the 1919 and 1922 eclipses. Using a similar argument to Emile Borel, he asserted that when 'rigorous experiments prove the theory to be true,

110 Costa, *A Teoria da Relatividade*, op. cit. (106), 42.
111 Costa, *A Teoria da Relatividade*, op. cit. (106), 34.
112 Costa, *A Teoria da Relatividade*, op. cit. (106), 34–5.
113 Costa, *A Teoria da Relatividade*, op. cit. (106), p. vi.

one can claim that the theory is true even if the considerations on which it stands will be proven false or totally or partially incorrect'.[114] Like all scientific contributions, it should be provisionally accepted; it could be improved but was not likely to be abandoned.[115]

In 1924 Ramos da Costa submitted to a Toronto international mathematics congress a paper entitled 'L'Enseignement des mathématiques doit être orienté pour l'étude de la relativité', later published in a Portuguese journal. Revealing understanding of the mathematical make-up of relativity and control of its recent developments, he concluded, '1st: Einstein's theory does not depend on completely new mathematics but on a drastic modification of old mathematics; 2nd: Einsteinian mathematics should be taught because it serves a theory which, if not true, is the most convenient one; 3rd: In order to be known, the popularization of the principles of Einstein's theory should start at the level of basic school. We deem this theory the *theory of the future*, the outcome of the unification power of laws obeyed by Nature's phenomena.'[116]

Gago Coutinho and the crusade against relativity

Less enthusiastic or even hostile reactions to the theory were expressed. Reinforcing the negative reaction of the astronomer Costa Lobo, mentioned previously, the admiral and geographer Gago Coutinho also became another outspoken opponent of relativity. Calling himself an 'ambulatory astronomer' or 'field astronomer',[117] he entertained personal and professional relationships with the personnel of the Lisbon observatory. In the period under consideration in this paper, he began discussing relativity in private correspondence exchanged with Oom. Some decades later, relativity became a major topic in his correspondence with Peres, who succeeded Oom in the directorship of the OAL.[118] In the meantime, Gago Coutinho became involved in public controversies that led to several popularizing publications in the science journals. A central personality in the geodesic mapping of Portuguese territories in Africa, he was the first, together with Sacadura Cabral, to fly across the Atlantic in 1922 from Lisbon to Rio de Janeiro. He turned into a heroic figure for his lusophone contemporaries. Politically conservative and outspoken in private as well as in public, in the letters written to Oom he discussed the fundamentals of the 'new mechanics'.[119] He enumerated those of

114 Costa, *Trilogia Einsteiniana*, op. cit. (106), 62.

115 Costa, *Trilogia Einsteiniana*, op. cit. (106), 62.

116 A. Ramos da Costa, 'O ensino das matemáticas deve ser orientado para o estudo da relatividade', *Revista de Obras Públicas e Minas e das Sciências Aplicadas à Indústria* (July 1925), **633**, 74–6, 76; original emphasis. An explanatory note revealed that the original paper submitted to the congress was not delivered, having been received after the deadline by the anti-relativist Costa Lobo, the Portuguese delegate to the congress.

117 OAL Archives. Ref. C-237: Correspondence G. Coutinho/F.Oom, letter, Coutinho to Oom, 27 February 1923.

118 OAL Archives. Ref. C-237 (1911/1956): Correspondence G. Coutinho /M. Peres. The correspondence about relativity starts in 1939.

119 OAL Archives. Ref.C-237: Correspondence G. Coutinho/F.Oom, letters, Coutinho to Oom, 27 February 1923, 10 July 1924.

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Einstein's statements that he could not understand and asked for help. At the same time he predicted he would 'continue living as if Newton's laws were approved by Parliament, legislation to the contrary having been revoked'. He considered relativity to be another 'outcome of a German offensive by a communist scientist'.[120] Believing that physical phenomena should be explained non-mathematically, he could not understand the finitude of the speed of light, dubbed the results of relativity 'optical illusions',[121] and proposed an alternative explanation for the advance of Mercury's perihelion.

Gago Coutinho seemed obsessed by relativity to such an extent that he visited Rio de Janeiro to see and listen to Einstein during his South American tour. His considerations were voiced in Brazilian newspapers and after his return to Portugal he certainly used his status to engage in a lively crusade against relativity. He clearly joined those who depicted the opposition between the advocates of relativity and those resisting it as a sort of religious clash between the 'fanatics of the religion of relativity' and the 'advocates of the positivist apostolate'.[122] His main objection, then as in the future, derived from the inapplicability of relativity to the real world in which we live. His experience as a geographer made him react to notions of time and space as relative concepts that were of no use to his daily geodesic practice in mapping colonial territories. He also objected to what he interpreted as the displacement of mechanics by electromagnetism mediated through the theory of relativity. He found no utility in a theory that only applied to the abstract world in which objects travelled at speeds close to that of light.

Gago Coutinho's visit to Brazil may well be considered the turning point in his strategy of opposition to Einstein's theory of relativity. He abandoned the calm of the private sphere to enrol fiercely in the public one. Thenceforth he articulated an anti-relativistic campaign whose success built on his social and scientific status as a national hero. He wrote a series of papers in the Coimbra journal *O Instituto* in 1926 and he restated his ideas in *A Seara Nova* (1930), then a periodical with a strong emphasis on the popularization of science, in which he engaged in a lively controversy with the mathematician Manuel dos Reis (1900–92), successor of Costa Lobo as director of the Observatory of Coimbra. This was about the time of Paul Langevin's visit to Portugal in 1929 and also the period when Reis published a comprehensive presentation on special and general relativity, written for his application for a full professorship at the University of Coimbra. Entitled *The Problem of Universal Gravitation*,[123] the text described the history of gravitational theories from Newton to Einstein, thus contributing to an easing of the process of appropriation of relativity within the then emerging Portuguese physics community.

120 OAL Archives. Ref.C-237: Correspondence G. Coutinho/F.Oom, letter, Coutinho to Oom, 27 February 1923.

121 OAL Archives. Ref.C-237: Correspondence G. Coutinho/F.Oom, letter, Coutinho to Oom, 10 June 1924.

122 Gago Coutinho, 'Palestras sobre a Teoria da Relatividade', in the Brazilian newspaper *O Jornal*, 6 May 1925. Cited in A. T. Tolmasquin, 'Constituição e diferenciação do meio científico brasileiro no contexto da visita de Einstein em 1925', *MAST. Notas Técnico-Científicas* (July 1996), 1–20, 17.

123 M. dos Reis, *O Problema da Gravitação Universal*, Coimbra, 1930.

Concluding remarks

While Portuguese astronomers were not the sole members of the Portuguese scientific community to appropriate relativity in different ways in their practice, they were particularly receptive to the 1919 expedition and afterwards became a very active group that has so far escaped historical study. Following the 1919 expedition, astronomers spelt out the patterns of their appropriation of relativity, reactions involving geographical and chronological gradations dependent both on individual idiosyncrasies and on community characteristics. In Portugal as in many European countries the responses to special and general relativity were conflated, essentially occurring simultaneously. The theoretical components to which astronomers often responded were diverse, including the astronomical consequences of general relativity theory, the mathematical make-up of special relativity, and the physical structure and implications of special and general relativity in terms of the redefinition of concepts basic to physics.

Portuguese astronomers mainly reacted to the astronomical and physical components of relativity. With the possible exception of Ramos da Costa, for them the mathematical make-up of the theory was not interesting as such, although mathematics was a strong component of the educational curriculum of most astronomers. The astronomers both of the OAL and of the Mozambique observatory responded to those aspects of special relativity that impinged directly on their astronomical practice. Their practice was associated with time determination and its dissemination as well as with longitude determination, which depended on time determination by synchronized clocks. The synchronization of clocks by electromagnetic signals introduced a new notion of time which, whether first considered as a convention or as a physical quantity, set them on the path to relativity. Such were the cases of Manuel Peres and of Ramos da Costa. This conclusion suggests an extension of Peter Galison's principal argument in *Einstein's Clocks, Poincaré's Maps* from the context of discovery to the context of appropriation in a peripheral zone such as Portugal.[124] Astronomers' interest in the physical consequences of special relativity were fostered by practical questions involving the synchronization of clocks and the determination and dissemination of time, not by the appeal of a theoretical discussion on the fundamentals of relativity. Just as clocks, trains, telegraphs and colonial empires were part of the real-world background to the theoretical breakthroughs offered by relativity, so clocks, ships, telegraphs and colonial affairs offered stimuli to the involvement of Portuguese astronomers with the *problématique* of relativity. Melo e Simas was not directly engaged in time determination but, like other Portuguese astronomers whose practice depended mainly on positional astronomy, he was interested in the results of expeditions to test light-bending. Following the expedition of 1922, Melo e Simas articulated an astronomical procedure to test the light-bending prediction that did not depend on solar eclipses, using the occultation of a star by Jupiter.

Being active participants in the First Republic, at times holding high political office, astronomers participated actively in the Republican project of social reform, which included popularization of various scientific activities among its many strategies to

124 P. Galison, *Einstein's Clocks, Poincaré's Maps: Empires of Time*, New York, 2003.

bring education to all. They often embarked on popularization activities in which they discussed the fundamentals of relativity theory, usually concentrating on the elements of special and general relativity by addressing the novelty of notions of space, time, matter and energy, curved space–time and the consequences of general relativity, and discussing agreements and disagreements with what they interpreted as being Einstein's ideas. During the period in question, when Portuguese astronomers were collectively responding to relativity, there were but isolated reactions by a few Portuguese mathematicians and physicists. Only in the 1930s, spurred by Langevin's visit, did they respond in more outspoken ways. Then the three communities – astronomers, mathematicians and physicists – were all involved simultaneously in the appropriation of relativity in the Portuguese context.