On May 29, 1919, at Roça Sundy, Principe island, Eddington confirms Einstein’s general relativity theory for the first time by photographing stars behind the obscured Sun during a total eclipse. History was made. At Sobral, Eddington’s astronomer colleagues photograph the same eclipse and also conclude that light from distant stars suffers a deflection when passing by the gravitational field of the Sun, in accordance with general relativity. With the confirmation of general relativity, a theory of gravitation at a fundamental level, physics became, once and for all, relativist and its future was outlined. The first world war had finished a few months before and the deep wounds between nations were yet to heal. Science wanted to be above it all showing that people could be united by a common goal. This year, the 100 years of this achievement was commemorated with the scientific conference “From Einstein and Eddington to LIGO: 100 years of gravitational light deflection” in Principe to celebrate this landmark event. We report here on this conference of celebration.
I. THE ECLIPSE AND THE LIGHT DEFLECTION OF 1919

On May 29, 1919, an eclipse of fundamental importance would take place. Stars behind a Sun hidden by the Moon could be seen due to the deflection of light rays that passed in the gravitational field of the Sun.

Einstein arrived at the final form of the theory of general relativity in November 25, 1915, when he presented it to the Prussian Academy of Sciences. In this theory, gravitational force was exchanged for spacetime curvature. Moreover, he deduced that for light incoming from distant stars grazing the Sun’s surface, the deflection of the light trajectory would be 1.75 arcseconds. Newton’s theory of gravitation gave half of that value, 0.875 arcseconds, and in addition there was the possibility of having no light deflection at all in the case light would not couple to gravitation. Einstein had also showed that following his theory, Mercury’s perihelion would advance in accord with the astronomical observations, this constituting an a posteriori proof of the theory, and that light would suffer a spectral redshift when it would climb a gravitational field, an experiment difficult to make. Thus, the observation of the light deflection in a solar eclipse would be the first direct proof of general relativity.

Eddington, a renowned astrophysicist from Cambridge with a deep knowledge of the theory, saw in the 1919 eclipse a supreme opportunity to test Einstein’s theory of gravitation, and convinced the English astrophysicists, that in turn determined that it was high time to test that prediction. The eclipse would pass along a track of 12 thousand km from west to east approximately along the equator line. Two expeditions, carefully planned by the royal astronomer, Frank Dyson, left England in the beginning of March 1919, stopped in Lisbon and then in Funchal where they parted. Eddington went to the island of Principe with his assistant Cottingham, a handicraftsman of clocks and other instruments. They lodged at Roça Sundy, in the plantation house that belonged to Jerónimo Carneiro and had all the necessary infrastructures. The Royal Greenwich Observatory astronomers, Crommelin and Davidson, went to Sobral, installing the telescopes and ceolostats in the horse track of the city’s Jockey Club since there was no race in the foreseeable future.

The eclipse of the Sun lasted 302 seconds, i.e., five minutes and two seconds. With instruments functioning at their limits, with better or worse weather, the two expeditions were a success, managed to capture photographs of stars, for which the corresponding light rays passed near the Sun, in plates that could constitute the first direct proof of the theory
of general relativity. With the eclipse finished, the astrophysicists returned to England to examine the collected images through instruments that measured the displacements of stars in photographic plates. Five months after, the results revealed that the observed stars near the solar disk during the eclipse were slightly shifted in relation to their normal position in the sky, in the amount predicted by Einstein’s theory, i.e., 1.75 arcseconds for stars near the Sun’s rim.

The results were then announced on November 6, 1919, in a meeting in the Royal Society jointly with the Royal Astronomical Society. The observations had confirmed the theory of general relativity and there was jubilation everywhere. The world now knew that the correct theory of gravitation was not Newton’s theory, but instead general relativity, and Einstein turned into a celebrity around the planet instantaneously. Physics, from this moment onward, became totally relativist, one now knew that particles along with their interactions, including gravitation, obeyed without doubt the laws of relativity. This is one of the most acclaimed events in the history of science.

It was the beginning of a long and beautiful success story. Black holes, gravitational waves, and cosmology are natural, new, and major consequences of the theory. One by one these consequences were unravelled, with general relativity passing in a magnificent manner a great number of tests, the most recent and impressive being the direct detection by LIGO (Laser Interferometer Gravitational-wave Observatory) of the first gravitational wave in 2015. This wave, in turn, was generated by the collision at cosmological distances of two black holes of around 30 solar masses each. The theory has transformed in a fundamental way our understanding of physics and astrophysics. It is also at the root of indispensable modern technologies, as the Global Positioning System, or GPS for short, only works with the proper synchronization between the clocks in the satellites and the clocks on the Earth taking into account relativistic corrections.

Besides confirming the theory of general relativity, the May 29, 1919, event showed once more that people from different nations could unite to a common aim. At the time, the first world war had finished not long ago, and English and German scientists, represented by Eddington and Einstein, respectively, gave hands looking to a better future.

The physics and astrophysics worlds united anew this year of 2019 to praise and celebrate this event. Given the historical character of this date, several celebrations were organized. Namely, in Principe, 100 years after, there was a conference “From Einstein and Eddington
to LIGO: 100 years of gravitational light deflection”, that had the hallmark of the Center for Astrophysics and Gravitation (CENTRA), a research unit of Instituto Superior Tecnico (IST). The action took place from May 26 to May 30, and the stage was at resort Bom Bom, 3 km away from Roça Sundy, the locus of Eddington’s observations. There was also further celebrations in Principe, Sobral, Lisbon, Rio de Janeiro, and London.

II. THE SCIENTIFIC CONFERENCE IN PRINCIPE IN 2019: CELEBRATION OF THE HISTORY AND THE SCIENCE

In 2015 there were celebrations all around the planet for the one hundred years of general relativity, commemorating the publication by Einstein in November 25, 1915, of the final and definitive form of the theory. CENTRA having as a specific area of research the fundaments of general relativity, celebrated this date with a conference at IST “GR 100 years in Lisbon”, see [1].

Being the light deflection in the gravitational field of the Sun a first experimental test to general relativity after the theory was elaborated, its historical verification with success in the May 29, 1919, eclipse by Eddington and collaborators, had to be celebrated. Without doubt the 1919 eclipse is one of the most acclaimed events in the history of science and of great significance for physics in general. CENTRA, a center of astrophysics and gravitation with works in experimental tests of general relativity and other theories of gravitation as well, did want to celebrate this iconic date.

The authors of this article considered thereby opportune and coherent to link this notable confirmation to the scientific activities of CENTRA and of other Portuguese scientists working in this area. Thus, in December 2015, during the celebrations of the 100 years of general relativity, we started conversations for a scientific conference in the end of May 2019, to celebrate in turn the 100 years of the confirmation of general relativity through the light deflection by the Sun’s gravitational field in the eclipse of May 2019, 2019.

As the observations were done in Principe and Sobral, it would be natural that Portuguese scientists would organize the scientific celebration in Principe, a Portuguese territory at the time. The main objective of the conference would be to celebrate this historical date to reflect the legacy left by Einstein and Eddington related to the eclipse and to discuss the impressive subsequent developments on astrophysics and gravitation. It would be a conference to tread
history, share the extraordinary scientific advances, and to look into the future. The speakers would be chosen along these ideas. Taking into account that the scientific organization was from CENTRA, whose members have been developing notable research in these areas and are leaders or belong to leading international groups, several CENTRA members would be chosen as speakers, together with specialists from prestigious universities and institutions.

Having this in mind decisions were taken. The chosen dates were May 26 to May 30, 2019, precisely one hundred years after of the 1919 eclipse. The chosen venue in Principe for the scientific conference was resort Bom Bom. It distances 3 km in a straight line and 9 km by road to Roça Sundy, the place where Eddington made the observations. Eddington writes in the eclipse article report that when he and Cottingham arrived at Principe, after checking the best place to install themselves, they chose to mount the telescopes in Roça Sundy. Curiously, the name Sundy is an English spell of Sundi, that comes from Sumdim, that in the local language means Senhor Dias, a local land owner in the beginning of the 19th century. Within the topics of astrophysics and gravitation, it was established to focus on themes related to the confirmation of light deflection in a gravitational field and current themes at the frontier of general relativity, such as black holes, gravitational waves, and cosmology. That is why the conference title “From Einstein and Eddington to LIGO: 100 years of gravitational light deflection” was chosen. In relation to the speakers, members of CENTRA together with specialists and researchers in universities and institutes of prestige were selected. The speakers were fifteen, namely, Alessandra Buonanno from the Max Planck Institute in Potsdam, Ana Mourão from the University of Lisbon, Carlos Herdeiro from the University of Lisbon and University of Aveiro, Clifford Will from University of Florida and University of Paris, Frank Eisenhauer from the Max Planck Institute in Garching, Ilídio Lopes from the University of Lisbon, Ismael Tereno from the University of Lisbon, João Costa from the University Institute of Lisbon, John Barrow from the University of Cambridge, Jonathan Gair from the University of Edinburgh and from the Max Planck Institute in Potsdam, José Sande Lemos from the University of Lisbon, Pedro Ferreira from the University of Oxford, Thomas Sotiriou from the University of Nottingham, Ulrich Sperhake from the University of Cambridge, and Vítor Cardoso from the University of Lisbon. The conference webpage was put online [2] and the conference poster was made public, see Fig. 1 and [3].

The speakers and participants arrived on May 26 in Principe after one day stop over
FIG. 1: The poster of the scientific conference “From Einstein and Eddington to LIGO: 100 years of gravitational light deflection” in Principe.

in São Tomé and it was with enormous jubilation that we all have celebrated during the conference in Principe the 100 years of this historical eclipse. Resort Bom Bom situated by the sea shore in a marvellous place of the island with paradisiac beaches, has a seminar room surrounded by equatorial vegetation, inspiring for this conference of celebration. May 27 and 28 were dedicated to talks, in May 29 the stage was at Roça Sundy.

On the 27th there were four morning talks where the themes were experimental and observational tests of general relativity, gravitational lenses, compact objects, and numerical relativity. During the coffee break one could walk through the luxuriant nature and pho-
tographs were taken, see Fig. 2 and Fig. 3. In the afternoon there were four talks about black holes, their exterior, their interior, and on fundamental properties of the event horizon. A free discussion ensued which finished at 7pm. In the evening, Tim de Zeuw of the Max Planck Institute at Garching, that was also present in the resort Bom Bom talks, gave a talk for the general public about the future of astronomy in a reception at Roça Belo Monte.

On the 28th there were seven talks dedicated to tests of general relativity and cosmology. In the coffee breaks and in the afternoon debate there were discussions about the past and future of astrophysics and gravitation, where the historical foundation was always present with emphasis on the creative work of Einstein and Eddington. There were conversations about gravitational waves and what LIGO can still give us and what it is intended in the future with LISA (Laser Interferometer Space Antenna) an ESA project to put satellites in space to detect gravitational waves coming from supermassive black holes and from the primordial universe. There was also a debate about unification theories, that were initiated and promoted by Einstein and Eddington, and its union with quantum mechanics, and also

FIG. 2: The organizers of the scientific conference “From Einstein and Eddington to LIGO: 100 years of gravitational light deflection” in the middle of the luxuriant vegetation in resort Bom Bom, Principe. From left to right: Vitor Cardoso, José Sande Lemos, Carlos Herdeiro. Photograph taken by Ilídio Lopes in the morning of May 27, 2019.
FIG. 3: The speakers of the scientific conference “From Einstein and Eddington to LIGO: 100 years of gravitational light deflection” in front of the seminar room in resort Bom Bom, Principe. From top to bottom and from left to right: Pedro Ferreira; Alessandra Buonanno, Ismael Tereno, Cliff Will; João Costa, José Sande Lemos, Uli Sperhake; John Barrow, Carlos Herdeiro; Frank Eisenhauer, Ilídio Lopes; Jonathan Gair, Thomas Sotiriou, Vítor Cardoso, Ana Mourão. Photograph taken by Jorge Vicente during the morning coffee break on May 27, 2019.

how black holes can elucidate in a correct formulation of quantum gravitation, a theory yet to be elaborated. José Sande Lemos and Jonathan Gair recalled Donald Lynden-Bell from Cambridge University, their supervisor in the years 1980s and 2000s, respectively, a great admirer of Eddington. He occupied in the Institute of Astronomy, Eddington’s room with a famous curved door and where a photograph of the great astrophysicist hanged on the wall over the working table. The works finished at 7pm and there followed a reception in Casa Rosa, the official house of the governor in Santo António, where scientists and political representatives of São Tomé e Príncipe and Portugal participated.

On the 29th, the participants of the scientific conference were in Roça Sundy, see Fig. 4. At Sundy there was a public event with special celebrations exactly 100 years after the eclipse. Of particular relevance, the Principe and Sobral celebrations got together in a teleconference at 2:30pm Principe hour, 10:30am Sobral hour, for a joint celebration. The speakers, by this order, were the Prefect of Sobral Ivo Gomes, the Prime Minister of São
Tomé e Príncipe Jorge Bom Jesus, the President of the Regional government of Príncipe José Cassandra, the Governor of Ceará Camilo Santana, the President of the Brazilian Academy of Sciences Luiz Davydovich, the President of the Brazilian Society for the Progress of Science Ildeu Moreira, the Rector of the University of São Tomé e Príncipe Aires Bruzaca de Menezes, the President of the International Astronomical Unions Ewine Dishoeck, and the President of the Center of Astrophysics and Gravitation of Lisbon and President of the General Assembly of the Portuguese Society of Relativity and Gravitation José Sande Lemos. There were congratulations from all for this special moment.

The scientific conference in Príncipe appeared in CENTRA News [4], in IST News [5], and was covered by the New York Times [6]. For the history and science of the 1919 eclipse see [7]. There were many celebrations all over the world, we refer to some in the following.
III. OTHER CELEBRATIONS IN 2019

A. Eddington at Sundy in Principe

For the Principe celebrations there was an extensive educational and scientific project “Eddington na Sundy: 100 years after” organized by the coordinator Joana Latas in cooperation with several entities, in particular with the Principe Regional Government. It was a project with several fronts that is intended to have continuity, see [7]. An aim of the project was to attract the attention of the Principe inhabitants to the relevance of the 1919 observations and to science in general. Local celebrations occurred from May 25 to May 30, 2019, the high point happening at Roça Sundy on May 29, where during the day national and international figures were present. In that day the population of Principe showed its great hospitality to the hundreds of participants that came from abroad. An exhibition was opened in Roça Sundy itself on the detection of light deflection. The exhibition is now permanent. Principe and Sobral joined celebrations in a videoconference. The scientific conference gladly joined this comprehensive educational and scientific project.

B. Sobral

In Sobral there was a scientific conference and a major public event from May 26 to May 31, that was in tune with the expectations and the importance of the discovery.

C. Lisbon

A special number of Gazeta de Física, a Portuguese journal that disseminates and promotes physics in general, was published in May 2019 to celebrate the events in Principe and in Sobral [9][10]. An exhibition opened in May 2019 in the National Museum of Natural History and Science of the University of Lisbon with the title “E3 - Einstein, Eddington and the Eclipse”. The XXIX Astronomy and Astrophysics National Meeting, this year organized at Instituto Superior Tecnico, University of Lisbon, was dedicated to Eddington and the eclipse, see [11].
D. Rio de Janeiro

At Rio de Janeiro National Observatory, house of its illustrious director Henrique Morize, that was present in Sobral to observe the solar corona and helped the English expedition in many ways, there was a celebration meeting in May 2019, just before the Sobral event.

E. London

In London there was a public event on November 6, 2019, organized by the Royal Astronomical Society celebrating de historical meeting of November 6, 2019, that was presided by J. J. Thomson, the man of the electron and president of the Royal Society at the time, that gathered the two societies to officially announce the results of the measurements of the light deflection by Dyson, Crommelin, Davidson, and Eddington, that confirmed Einstein’s theory of gravitation.

F. Future

We hope that this May 29 date be always commemorated, with particular emphasis at each 100 years from 1919 onward, as we have done now for the first time, and that Einstein, Eddington, Principe, and Sobral be remembered in this date. It will show that gravitation theory, realized in general relativity or eventually in some other more fundamental theory, continues prosperous.

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[1] https://centra.tecnico.ulisboa.pt/network/gr100yearsinlisbon/
[2] https://science.esundy.tecnico.ulisboa.pt/en/
[3] https://science.esundy.tecnico.ulisboa.pt/en/poster/
[4] https://centra.tecnico.ulisboa.pt/news/?id=5610
[5] https://tecnico.ulisboa.pt/pt/noticias/100-anos-depois-do-eclipse-que-confirmou-a-teoria-da-relatividade/
[6] https://www.nytimes.com/2019/05/28/science/solar-eclipse-einstein-physics.html.
[7] J. P. S. Lemos, “Shadow of the Moon and general relativity: Einstein, Dyson, Eddington and the 1919 light deflection”, Revista Brasileira de Ensino de Física 41 suppl. 1, e20190260 (2019); [arXiv:1912.05587] [physics.hist-ph].
[8] http://esundy.org/index.php/en/homepage/
[9] A. J. S. Fitas, P. Crawford, and J. P. S. Lemos (editors), Einstein, Eddington, Eclipse (Número especial dedicado à exposição E3 - Einstein Eddington e o Eclipse, Gazeta de Física, Lisbon, 2019).
[10] J. P. S. Lemos, C. A. R. Herdeiro, and V. Cardoso, “Einstein, Eddington and the consequences of general relativity: Black holes and gravitational waves”, [arXiv:1911.01959] [physics.hist-ph] (2019); for the Portuguese version see J. P. S. Lemos, C. A. R. Herdeiro, and V. Cardoso, “Einstein e Eddington e as consequências da relatividade geral: Buracos negros e ondas gravitacionais”, in Einstein, Eddington, Eclipse, editors A. J. S. Fitas, P. Crawford, and J. P. S. Lemos (Número especial dedicado à exposição E3 - Einstein Eddington e o Eclipse, Gazeta de Física, Lisbon, 2019), p. 36.
[11] https://centra.tecnico.ulisboa.pt/network/costar/enaa2019/