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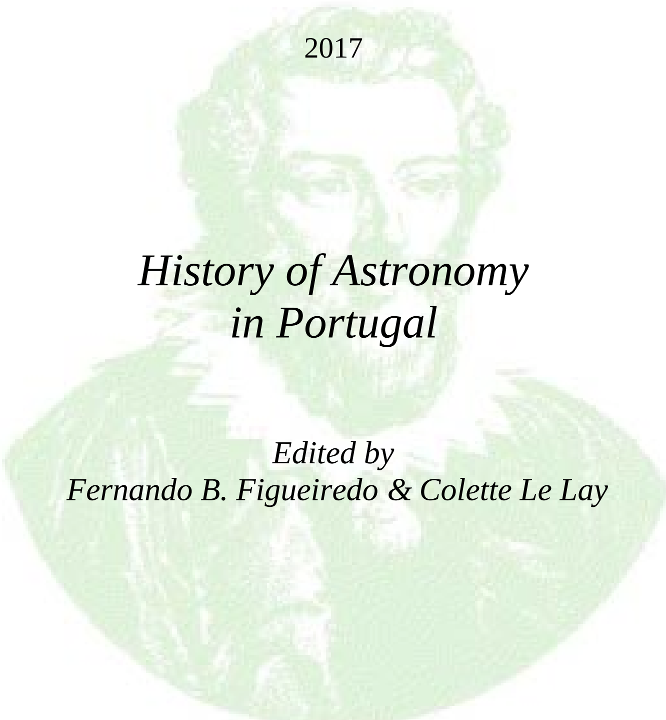

History of Astronomy in Portugal

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Costa Lobo (1864-1945), the Coimbra Spectroheliograph and the Internationalisation of Portuguese Astronomy[1]

Vitor Bonifácio*

Abstract

At the beginning of the 20th century, Portuguese astronomy was still firmly anchored in the past. Only astronometric research was pursued and Portuguese professional astronomers seldom published their results. This situation changed in the 1910s thanks to the actions of Francisco Miranda da Costa Lobo (1864-1945). Costa Lobo initiated the construction in Coimbra of a world-class solar observing facility in close co-operation with observatory astronomers based in Meudon. Recognising the importance of international relations, he made frequent scientific travels and disseminated his research to a wide audience. In this paper we improve on the current understanding of the Coimbra spectroheliograph installation. We argue that Costa Lobo's actions, foreign support and social skills played a fundamental role in the internationalisation of Portuguese astronomy.

Keywords: Francisco Miranda Costa Lobo, Henri Deslandres, solar studies, international co-operation, spectroheliograph, Coimbra Astronomical Observatory, Meudon Observatory.

Résumé

Au début du XX^e^ siècle, l'astronomie portugaise était ancrée dans le passé. Seules les recherches astrométriques sont poursuivies et les astronomes professionnels portugais publient rarement leurs résultats. La situation change dans les années 1910 en raison des actions de Francisco Miranda da Costa Lobo (1864-1945). Costa Lobo a été responsable de la construction à Coimbra d'une installation d'observation solaire de classe mondiale en étroite coopération avec les astronomes de l'observatoire de Meudon. Reconnaissant l'importance des relations internationales il a fait de fréquents voyages scientifiques et diffuse ses recherches vers un public vaste. Dans cet article, nous essayons d'améliorer la compréhension actuelle sur le processus d'installation du spectrohéliographe à Coimbra. Nous soutenons que les actions de Costa Lobo, le soutien étranger et ses compétences sociales ont joué un rôle fondamental dans l'internationalisation de l'astronomie portugaise.

Mots-clés : Francisco Miranda Costa Lobo, Henri Deslandres, études solaires, coopération internationale, spectrohéliographe, Observatoire Astronomique de Coimbra, Observatoire de Meudon.

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William Wollaston (1766-1828) discovered in 1802 the solar spectra dark divisions, today called absorption lines. These were extensively mapped by Joseph Fraunhofer (1787-1826) in the 1810s (Meadows, 1970). A paper read by Gustav Kirchhoff (1824-1887) at Berlin Academy on 27 October 1859 explained their origin. His interpretation authorised "conclusions therefrom respecting the material constitution of the atmosphere of the sun, and perhaps also of the brighter fixed stars" (Kirchhoff, 1860, p. 195).

Two years earlier, in 1857, the Portuguese government had approved the construction of a new astronomical observatory devoted to high-precision stellar astrometric measurements. Both the Coimbra University and the Lisbon Navy astronomical observatories had been deemed uncompetitive by international standards as a result of being poorly located and underequipped (Bonifácio *et al.*, 2009).

The first Portuguese astrophysical studies were to take place in 1870 in the wake of the total solar eclipse of 22 December. Prior to this date, no national expertise existed in the fields of astronomical spectroscopy and photography. Wishing to perform useful observations, the Portuguese scientific community sought advice from international colleagues, acquired – with a generous government support – new instruments and organised an eclipse expedition to the Algarve. Rain did not allow a successful observation but in the aftermath of the expedition they acquired three equatorial telescopes and one photoheliograph. Spectroscopes were also distributed to Infante D. Luiz Meteorological Observatory, Tapada da Ajuda Astronomical Observatory and Coimbra University Mathematics and Philosophy faculties. The latter had the responsibility of Coimbra University Astronomical and Meteorological observatories, respectively. Lacking willpower to face bureaucratic difficulties and/or to pursue a research project the Coimbra University Meteorological Observatory initiated no studies. The conceptions of astrometry and astrophysics confronted each other within Coimbra University Astronomical Observatory. Astrometry and ephemeris calculations remained the main observatory work following a botched attempt of reform in 1870-71 (Bonifácio, 2009). Tapada da Ajuda Observatory research project stayed faithful to its conception (Raposo, 2010, p. 296). At D. Luiz Meteorological Observatory in Lisbon, João Carlos de Brito Capello (1831-1901) introduced a solar photography project. He sought to obtain a daily record of the solar surface and highly magnified sunspot photographs in order to apprehend the interplay between Earth's magnetic field and solar activity. The project lasted until the early 1880s. The lack of staff and Jules Janssen's solar photographs supposedly caused the end of the project. Nevertheless, Capello maintained for a few years a worldwide network of correspondents and took some of the best solar photographs available (Bonifácio *et al.*, 2007).

The closure of the Navy Observatory in 1874 led to rethinking how astronomy was taught in Lisbon. A new observatory was built at Lisbon Polytechnic School. The research goals – in astrophysics and astronomical photography – of this new establishment were planned to complement the astronometric activity of Tapada da Ajuda Observatory. Financial difficulties prevented the acquisition of the 11-inch Alvan Clark & Sons telescope, which had been ordered. At the time, this instrument would be the best photographic telescope in Europe. Later, Henry Draper (1837-1882) used it to obtain the famous Orion nebula photograph on 30 September 1880. The observatory ended as a mere teaching facility (Bonifácio, 2009).

By the early 1880s, all Portuguese astrophysical research initiatives had either failed or had been interrupted. Portuguese professional astronomers at Coimbra and Lisbon either pursued research in astrometry or gave up research entirely. In the following decades, the situation remained unchanged and no new astrophysical equipment was acquired (Bonifácio, 2009). The inadequacy of Portuguese astrophysical instruments became apparent on the occasion of the total solar eclipse of 1900. In 1905, the astronomer Frederico Oom (1864-1930) from Tapada de Ajuda denied a possible Portuguese expedition to observe the total solar eclipse of 30 August 1905 and remarked:

> Astronomical expeditions – sometimes to exceedingly distant places – to observe solar eclipses cannot be justified unless there is a certainty or a likelihood to obtain relevant scientific data (Oom, 1905, p. 487).[2]

The rise of astrophysics followed Kirchhoff's discovery. At the end of the 19th century this new field already took the centre stage of astronomical research (Meadows, 1970; Gingerich, 1984, Herrmann, 1984; Hearnshaw, 1984, 1986, 2009). In Portugal, professional astronomers made no attempt to pursue astrophysical studies until 1912, when a 47-year-old Coimbra University professor, Francisco Miranda da Costa Lobo (1864-1945) pushed through the construction of a state-of-the-art solar observatory.

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[2] The paper author translated all non-English quotes. "As expedições astronomicas para ir - ás vezes bem longe - observar eclipses do sol, não podem hoje justificar-se de modo algum, senão para quem, nessas expedições, tem a certeza ou a probabilidade de obter dados interessantes para a sciencia" (Oom, 1905, p. 487).

Francisco Miranda da Costa Lobo Early Life

Before Costa Lobo taught astronomy at the University, he published in a Portuguese scientific journal an astronomical paper detailing the partial lunar eclipse observation of 7 January 1898. He also led the already mentioned ill-equipped Coimbra expedition to observe the total solar eclipse of 28 May 1900 (Bonifácio, 2009). The situation was strikingly different to what would happen after 1912.

Francisco da Costa Lobo was born in 1864 and enrolled at Coimbra University in 1879 where he attended both Mathematics and Philosophy courses. He obtained a Ph.D. in Mathematics in 1885 and was soon hired as a faculty professor. In 1887, Costa Lobo became the astronomy substitute teacher. Since astronomers' positions were legally tied up to specific mathematical course units, he was appointed the third astronomer of the University Astronomical Observatory. In 1893, he became a fully fledged astronomy professor and the second astronomer. In 1904, he was promoted first astronomer before acceding to the Observatory directorship in 1922 (Univ. de Coimbra, 1888, 1894, 1904; República Portuguesa, 1922; Rodrigues, 1992; Bonifácio, 2009). During this period and despite his long involvement with astronomy, Costa Lobo – as far as it is known – did not publish any original research. There is nevertheless evidence that he followed astronomical developments and incorporated them into his teaching. The Astronomy course unit content – approved on 19 February 1903 following a reorganisation of the Mathematics course – included astrophysics and astronomical photography subjects. Within the national context, the novelty of this syllabus may be fully appreciated if compared to what was then taught at Lisbon Polytechnic School (Bonifácio, 2009, p. 347).

The question which arises is what brought about Costa Lobo's change? Amorim (1955) states that Costa Lobo's newfound scientific focus was a consequence of the revolution which overthrew the monarchy on 5 October 1910. As a monarchic, Costa Lobo reduced his political activities under the new republican regime. There is no doubt that Costa Lobo had been politically active since at least 1889 when he was appointed Coimbra's district substitute civil governor. In 1905, he was elected Member of Parliament. He did not run in April 1906 but was elected in August 1906, April 1908 and August 1910. (Amorim, 1955; Mónica, 2004) Still, Costa Lobo's biography shows that he maintained a multitude of interests after the republican revolution. For instance, in May 1911, he attended Madrid's ninth *Agricultural International Congress* as representative of the *Sindicato Agrícola de Coimbra* (Agricultural Union of Coimbra) (Commission Internationale d'Agriculture, 1912). In the 1910s he was involved in several political or politically motivated associations such as Causa Monárquica (Monarchical

Cause), União Patriótica (Patriotic Union) and Liga Nacional (National League). He briefly returned to parliament between 1918 and 1919 (Leal, 1998; Mónica, 2004).

An Auspicious Series of Events

According to one of Lobo's recollection in 1925 he "had the opportunity to visit [in 1907] the major European observatories, in order to get Coimbra Astronomical Observatory a solar facility equipped with the second type of spectroheliograph knowledgeably envisioned by Mr. Deslandres"[3] (Lobo, 1925a, p. 34). Later, he wrote that the 1907 trip convinced me of the advantages offered by Meudon's instrumental setup to perform solar atmospheric researches (Lobo, 1932a, p. 7). Despite our best efforts we were unable to independently confirm Costa Lobo's trip of 1907 really happened. No mention to it is found in the Faculty of Mathematics meeting minutes. In 1907, between 2 January and 11 April, Costa Lobo attended most of Parliament sessions but what he did during recess is open to speculation (Portugal, 1907). Furthermore, Costa Lobo was absent from the list of delegates attending the third conference of the International Union for Cooperation in Solar Research held at Meudon between 20 and 23 May 1907 (Anonymous, 1914a). At the time, Meudon's new spectroheliograph upon which the instruments in Coimbra would later be based was in an advance state of construction. It was fully operational in 1908 (Mouradian & Garcia, 2007). As no independent confirmation of Lobo's 1907 trip was found, we conclude that if it occurred it was likely to be a private affair and as such Costa Lobo had no obligation to procure new instruments for the Coimbra Observatory. Also, according to Lobo, the support from Meudon's Observatory director Henri Deslandres (1853-1948) only started in 1912 (Lobo, 1925a, p. 35).

On 19 August 1907, a new law increased the autonomy of higher education establishments. It allowed them, amongst other provisions, to manage their financial resources in order to fund scientific journeys abroad. Coimbra University professors first took advantage of this alteration in 1908 (Remédios, 1912). In July 1910 Costa Lobo was chosen by his colleagues from the Faculty of Sciences to undertake two scientific missions

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[3] "quando tive ocasião de visitar os principais observatórios da Europa, exactamente com o propósito de conseguir para o Observatório Astronómico de Coimbra uma instalação para o estudo do Sol, pelo segundo tio de spectroheliographo, sabiamente imaginado por Mr. Deslandres".

abroad to study matters related to his courses. Each mission could not exceed three-months.[4] The motivations for these missions appeared to be pedagogic rather than scientific.

We suspect Costa Lobo's plan likely developed between 1910 and 1912. It was helped by a set of auspicious coincidences as detailed below.

By the end of 1911, Costa Lobo had already completed his missions abroad. Unfortunately, the required mission documents reporting the whereabouts remain unknown. Consequently, we do not know which establishments were visited and when. What is certain is that from 1910 onwards, Costa Lobo became an avid scientific traveller. In June 1911, he attended the third meeting of the Asociación Española para el Progresso de las Ciencias (Spanish Association for the Advancement of Science) held in Granada where he presented two short papers. One discussed azimuth determination with meridian instruments and the other speculated upon the nature of Newton's gravitational force (Lobo, 1912a, 1912b). More importantly, we believe was his attendance to two communications detailing contemporaneous Spanish solar research. Ricardo Garrido (1878-1959) presented an overview of sunspot spectral studies emphasising the work carried out at Cartuja Observatory while presenting several still unanswered questions. After the presentation, photographs of sunspot spectra and equipment were shown to the audience (Garrido, 1912). The paper by the astronomers Francisco Iñiguez e Iñiguez (1853-1922) and Victoriano Fernández Ascarga (1870-1934) reviewed spectroheliograph development, types and usages before describing the characteristics of the new Madrid Observatory instrument. According to this paper it is clear that installing one of these instruments was a complex endeavour (Iñíguez and Ascarza, 1912). Following the total solar eclipses of 1900 and 1905, there was in Spain a surge of interest for astrophysical studies, particularly those related to the sun (López Arroyo, 2004; Ruiz-Castell, 2008).

Costa Lobo suddenly gained international visibility thank to his 17 April 1912 observation of the solar hybrid eclipse. The eclipse lasted an extremely short interval, 0.2 s according to modern calculations. It provided, in theory, a good opportunity to improve several astrometric parameters, e.g. the apparent diameter of the Moon. Costa Lobo organised a modestly equipped expedition to Ovar with his students and managed to film the eclipse with a borrowed movie camera. We are unsure if scientific

[4] Universidade de Coimbra (1910), "Acta da Congregação da Faculdade de Mathematica, 10 de Julho, 1910" in *Actas da Congregação da Faculdade de Mathematica, vol. 7, 1886-1911*, Unpublished document, Arquivo da Universidade de Coimbra, IV-1a-D-3-1-81, Coimbra (Portugal).

or commercial arrangements motivated this expedition but after analysing the film frames Costa Lobo deduced an unexpected lunar polar flattening. This first astronomical hypothesis solely based on cinematographical observations was presented by Deslandres, on 20 May, to a session of the Académie des Sciences de Paris and it was published on the 28th May *Comptes rendus* volume (Lobo, 1912c). The results of the movie displaying the eclipse were discussed in a series of articles published in 1912 and were quickly disregarded by the astronomical community which favoured an explanation of the observations based upon the irregularities of the lunar profile (Bonifácio *et al.*, 2010). Nevertheless, the event allowed Costa Lobo to obtain the regard of the astronomical community and led to exchanges with Deslandres. Since he was advised not to present a follow-up communication to the *Comptes rendus,* Costa Lobo published instead an extensive paper in a new Coimbra University journal (Lobo, 1912d). In an approach, which was characteristic to Lobo, the article was published in French and we know that he circulated it. Three offprints appear in Paris Observatory Library Catalogue – two of which contain dedications by the author. Still, in 1912, Costa Lobo visited South Kensington solar observatory – a leading solar research institution then.[5]

The Coimbra Spectroheliograph

Before the end of 1912, Costa Lobo's project was already defined and Deslandres' support was secured. In 1913, the large spectroheliograph with 40 cm diameter mirrors had already been ordered from the French maker Amédée Jobin (1861-1945).
Costa Lobo's initiative had the potential to contribute to the advancement of solar studies., as may be ascertain by the Spectroheliograph committee's resolution adopted at the International Union for the Solar Research Bonn meeting, in 1913:

> That spectroheliographs of high dispersion capable of recording the details of the higher atmosphere with the K3 (calcium) or Hα lines combined with image-forming apparatus of long focus, should be installed wherever possible. (Anonymous, 1914c, p. 171)

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[5] Solar Physics Observatory (1913), *Report upon the work of the Solar Physics Committee done in the Solar Physics Observatory, South Kensington from 1st January to 31st December 1912*, Unpublished document, Cambrige Library, Obsy B1 (ii), Cambridge (United Kingdom).

The spectroheliograph was a class of instruments independently developed by George Ellery Hale (1868-1938) and Henri Deslandres in the 1890s. In these instruments, a spectrograph entrance slit isolates a particular area of the solar surface image formed by an objective lens. Following dispersion by a prism train or a diffraction grating a second slit isolates a single spectral line. This produces a monochromatic image of the solar area selected by the first slit. In order to obtain a solar disk photograph, the slit and sun image have a relative motion. The spatial and wavelength resolutions of the instrument are defined by the first and second slits, respectively. In Hale's first spectroheliograph, which became operational in 1892, the two slits moved synchronously. A monochromatic image of the Sun was recorded on a fixed photographic plate placed after the second slit. In his model of 1907, Deslandres synchroniszed, instead, a movable objective and a movable photographic plate (Deslandres, 1909; Hearnshaw, 2009). This set-up lack of *a priori* constraints on the size of the instrument dispersion component was its main advantage. The Coimbra spectroheliograph is a copy of this model.

The beginning of the First World War considerably slowed down Costa Lobo's plans. The completion of the instrument was delayed until the 1920s. Still, this was a remarkable achievement when one takes into consideration the complex political and economic situation of the first Portuguese Republic. Political instability was widespread throughout this period. Between 1910 and 1925, 39 Republican governments succeeded each other. Public finances suffered and the country's slight 1910-1911 budget surplus became a large deficit by 1925-1926. High inflation and the rapid devaluation of the national currency (escudo) – especially after the war – diminished the purchasing power of foreign goods (Mata & Valério, 2003). On 6 May 1921,the need to increase the budget of the Observatory to take into account the sharp price increase of the ordered instruments due to the exchange rate variation was mentioned in parliament (Silva, 1921). Four months later, on 5 September, a joint bill by the Ministers of Finance and Education proposed a transfer of funds from the University's personnel budget to the purchasing of astronomical instruments (Ferreira & Machado, 1921). The proposal was not discussed since Parliament was suspended on 17 September. The year 1921 was a particularly troubled one. There were 6 successive governments and the upheaval of 19 October known as the "Bloody Night" (Maltez, 2005).

In August 1922, the Ministers of Education and Finance sent to parliament two important proposals for the future development of the Astronomical Observatory of Coimbra University. The first proposal advocated changing the observatory regulations while the second one authorised a fund transfer between the Ministry of Education budget and the Observatory budget. On 2 September 1922 the bill was approved and 65.000$ were provided for the "full payment of the instruments intended for astronomical observation and research" (Anonymous, 1922). On 23 September, Costa Lobo was appointed director of the Observatory. The previous director's scope of action was reduced to the supervision of the Observatory Ephemeris. (Ministério de Instrução Pública, 1922). Conditions were now in place to start-up a research programme at the observatory as soon as the instrument was fully functional.

The Coimbra spectroheliograph was inaugurated on 12 April 1925 (Lobo, 1944). Later that year, Costa Lobo predicted that from the month of October, the Coimbra Astronomical Observatory will finally lend to solar studies the assistance previously planned (Lobo, 1925b). In July, the Coimbra new facility was announced at the IAU General Assembly held in Cambridge, UK. Regular observations began in January 1926 (Lobo, 1932a).

One should point out that the setbacks due to the First World War did not diminish the relevance of the Coimbra spectroheliograph in the international context as can be inferred, for example, by Deslandres's 1924 report:

> Until now only three observatories photographed the upper [solar atmospheric] layer with a large spectroheliograph. These are the observatories of Mount Wilson in California, Kodaikanal in India and Meudon. Soon it will be necessary to add the Coimbra Observatory (Portugal) and a large solar observatory, which is under construction in the eastern part of Australia.[6] (Deslandres, 1925, p. 8)

Another indicator of Coimbra's instrument importance is the small number of spectroheliographs installed until 1925 (table 1).

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[6] "Or jusqu'ici trois observatoires seulement photographient la couche supérieure avec un grand spectrohéliographe ; ce sont les observatoires de Mont Wilson en Californie, de Kodaikanal aux Indes et celui de Meudon. Bientôt il faudra ajouter l'observatoire de Coïmbra (Portugal) et un grand observatoire solaire qui est en contruction dans la partie Est de l'Australie." Henri Deslandres (1925), *Rapport sur l'observatoire d'astronomie physique de Meudon. Année 1924*, Unpublished document, Bibliothèque de l'Observatoire de Paris, Paris (France).

Observatory	*Date*
Kenwood, USA	1892
Observatoire de Paris, France	1894 (1)
Observatoire de Meudon, France	1906 ; 08
Yerkes Observatory, USA	1903 ; 04
Kodaikanal Observatory, Kodaikanal, India	1904 ; 09
Potsdam Astrophysical Observatory, Germany	1904
South Kensington Solar Physics Observatory, United Kingdom	1904 (2)
Observatorio del Ebro, Tortosa, Spain	1904
Mount Wilson, California, USA	1905 ; 08 ; 12
Arosa Astrophysical Observatory, Switzerland	1911
Observatorio Astronomico de Madrid, Spain	1912 (3)
Cambridge Solar Physics Observatory, United Kingdom	1913
Tokyo Astronomical Observatory, Japan	1920
Utrecht solar tower, Holand	1922
Potsdam Astrophysical Observatory, Germany	1924
Observatorio Astrofisico di Arcetri, Firenze, Italy	1925
Observatorio Astronómico da Univ. de Coimbra, Portugal	1925

Table 1- Spectroheliographs installed prior to 1926. Dates and instruments should be considered as indicative due to disagreements between different references. More than one date, e.g. Meudon 1906; 08 indicates more than one instrument. Notes: (1) transferred to Meudon Observatory, (2) transferred to Cambridge Solar Physics Observatory, (3) Closed before 1920.

The Coimbra-Meudon Co-operation

The existence of a twin instrument placed at a different – and sunnier – location was surely a tempting proposition to Henri Deslandres. As a result, in 1912, a symbiotic relationship was initiated and lasted until today. In particular, the know-how and support of Meudon Observatory were fundamental to install the spectroheliography at Coimbra.

In his Meudon Observatory report for the year 1921, Deslandres (1922, p. 7) wrote:

> These first maps of the solar upper layer relate mostly to a series of observations made in the fine season – winter in Meudon – for the Sun is sometimes hidden for several consecutive days. The survey displays gaps which are troublesome. This difficulty will be overcome by an agreement with Mr Costa di [sic.] Lobo, Director of Coimbra Observatory (Portugal) who, be-

> fore the war, ordered a spectroheliograph identical to ours. In Portugal, the sky is pure during winter and the two Observatories will exchange their photographs.[7]

Similar statements are also found in other yearly reports (Deslandres, 1924, 1925).[8]

In the meantime, in 1923, Costa Lobo's son, Gumersindo da Costa Lobo (1896-1952), who was second assistant at the Coimbra University Faculty of Sciences did – at his own expense – an internship at Meudon Observatory (Lobo, 1944). He then became "responsible for all installation services and scientific research of the Astrophysics department of the [Coimbra] Astronomical Observatory"[9] (Amorim, 1955, p. 24). In 1925, Lucien d'Azambuja (1884-1970), who was an astronomer in Meudon

> was sent to Portugal from 13 March to 14 April to finalise the installation of Coimbra Observatory spectroheliograph which is identical to ours. Then, in the month of April, he made a complete study of a 25 cm diameter and 4 m focal length objective lens ordered by Coimbra Observatory from the manufacturer Jobin. The lens was shipped to Portugal, after necessary modifications.[10] (Deslandres, 1926, p. 21)

As soon as the Coimbra spectroheliograph became operational the desired exchange of photographic plates between the two observatories started.

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[7] "Ces premières Cartes de la couche supérieure se rapportent la plupart à des séries d'observations faites dans la belle saison ; car, en hiver, à Meudon, le Soleil est caché parfois pendant plusieurs jours consécutifs, et le relevé offre des lacunes qui sont gênantes. Cette difficulté sera levée par une entente avec M. Costa di Lobo, directeur de l'Observatoire de Coïmbra (Portugal), qui, avant la guerre, avait commandé un spectrohéliographe identique au nôtre. Au Portugal, le ciel est pur pendant l'hiver ; et les deux Observatoires devaient échanger leurs épreuves."

[8] Henri Deslandres (1926), *Rapport sur l'observatoire d'astronomie physique de Meudon. Année 1925,* Unpublished document, Bibliothèque de l'Observatoire de Paris, Paris (France).

[9] "foi encarregado de todos os serviços de instalação e investigação científica da secção de Astrofísica do Observatório Astronómico".

[10] "a été envoyé en Portugal du 13 mars au 14 avril, pour mettre au point le spectrohéliographe identique au nôtre, organisé par l'Observatoire de Coïmbra. Puis, au mois d'avril, il a fait une étude complète d'un objectif de 25 cm et de 4 m de distance focale commandé par l'observatoire de Coïmbra au constructeur M. Jobin. L'objectif après une retouche jugée nécessaire a été expédié en Portugal."

Meudon series of observations of hydrogen, Hα, and calcium, K1 and K3, spectral lines began in 1919. In order to fill observation gaps record spectrograms were exchanged with other observatories (Deslandres, 1925; Mouradian & Garcia, 2007, p. 3). In particular, from 1926 to 1934, the Kodaikanal and Mount Wilson observatories provided the Hα spectral images while Coimbra Observatory supplied the K3 ones. In this period, an average of 229 Calcium K3 images was obtained each year in Meudon while Coimbra Observatory contributed with approximately 64 extra images per year. Kodaikanal and Mount Wilson observatories each provided a similar number of Hα photographs yearly (table 2).[11]

		Year								
Line	*Obs.*	*1926*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*
K_1	M	168	188	264	235	209	189	211	209	189
K_3	M	232	231	219	267	225	229	230	225	206
K_3	C	76	122		96		70	104	63	81 (1)
Hα	M	191	197	235	249	226	200	227	209	211
Hα	K	123 (2)		30		29	36	27	19	21 (1)
Hα	W	70		63 + 95 (3)			84	89	87	46 (1)

Table 2 - Number of spectroheliograms in the K1, K3 and Hα lines in Meudon's database from 1926 to 1934. Images are from Meudon (M), Coimbra (C), Kodaikanal (K) and Mount Wilson (W) observatories. Notes: (1) number includes first semester of 1935, (2) number from 1925 to 1927, (3) from the reports it is not clear if these numbers are independent.

Copies of images by Meudon Observatory were also sent abroad if requested. Kodaikanal received K3 and Hα images yearly. In Meudon reports we found only two occasions when images were sent to Coimbra: in 1929 and 1932, 9 and 97 images, respectively. Are these from different dates? We do not know yet but this is something to be investigated.

Two points are important, in our opinion. One is the small number of world-class solar facilities interchanging spectrograms. The other is that the exchange of images began under the auspices of the International Astronomical Union (IAU) (Esclangon, 1935, p. 32)

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[11] Henri Deslandres (1927-1928), *Rapport sur l'observatoire de Paris. Années 1926 à 1928*. Ernest Esclangon (1930-1936), *Rapport sur l'observatoire de Paris. Années 1929 à 1935*. Each year corresponds to a different volume (see the bibliography section).

Coimbra astronomers were also interested in obtaining Hα images. A diffraction grating offered by Robert Williams Wood (1868-1955) was tested by Marguerite Roumens (1898-1985), Azambuja's future wife, in Meudon. The grating flaws, she concluded, prohibited its intended use (Esclangon, 1932, p. 32). In 1932, Roumens found the "new grating to be far superior to the previous one"[12] (Esclangon, 1933, p. 40). More importantly, one finds once more the idea that it will facilitate the exchange between the two observatories.

> It will enable the Observatory of Coimbra, which, by sending complementary photographs, participates in the survey of the chromospheric phenomena that we are pursuing, to obtain images Hα of quality comparable to that of the images Hα of Meudon.[13] (Esclangon, 1933, p. 40)

Good Hα images were only taken in Coimbra from 1941 onwards (Silva, 1969).

Nevertheless, obtaining regular observations and exchanging them was only the beginning of a solar physics section at Coimbra Observatory. Costa Lobo published a few papers analysing the data already collected in international journals (Lobo, 1926, 1927, 1929). In 1932, he started the periodic publication of the observatory results (Lobo, 1932b, 1932c). This new initiative by Costa Lobo, though logical, was a first for Portuguese observatories. The publication was well received. A IAU resolution at the 1932 general assembly stated that the:

> commission of Solar Physics – after examination of the publications of the Coimbra Observatory concerning the solar activity, and acknowledging the great importance of that work considers that the Observatory of Coimbra – should be able to continue to make these observations and this important publication. It is in fact necessary for the continuation of the international work that the Coimbra Observatory sends its results to Meudon and Zürich in order to make the synoptical charts and the character figures more complete. These are requirements that the Coimbra Observatory will be able to

[12] "Le nouveau réseau s'est révélé très supérieur au précédent."

[13] "Il permettra à l'Observatoire de Coimbra qui, par l'envoi de clichés de complément, participe au relevé des phénomènes chromosphériques que nous poursuivons, d'obtenir des images Hα de qualité comparable à celle des images Hα de Meudon."

> follow with its important publications and its international collaborations.[14] (Commission 12 (Physique Solaire), 1933, p. 283)

Coimbra Astronomical Observatory is now a full-fledged actor in the international solar research community. An opportunity the spectroheliograph provided.

Joining the International Community

After 1911, one also finds that Costa Lobo was committed to establish international scientific relations. Costa Lobo made the advantages of these relations clear. For instance, he explained that a scientific meeting

> always represents a remarkable event because it shows an immense collective effort by the intellectual elite in order to better human knowledge, make as much discoveries as possible. these discoveries are either speculative by providing new satisfactions to the spirit, or of practical nature which may contribute to new inventions able to improve human living conditions.[15] (Lobo, 1922, p. 166)

After the First World War, other arguments were weighted in. In his opinion it was "the duty of the nations to preserve themselves and bind in accordance to their affinities in order to avoid or at least mitigate such horrific cataclysms."[16] (Lobo, 1922, p. 169) Following his attendance of the third Spanish Association for the Advancement of Science meeting held in Granada in 1911, Costa Lobo not only attended the association meetings of

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[14] "La Commission de Physique Solaire a examiné les publications de l'Observatoire de Coimbra au sujet de l'activité solaire : elle reconnait la valeur de ces travaux et elle est d'avis qu'il est nécessaire pour la continuation des recherches internationales que l'Observatoire de Coimbra envoie ses résultats à Meudon et à Zurich afin que les Cartes synoptiques et les Nombres caractéristiques soient rendus plus complets. La Commission espère bien que l'Observatoire de Coimbra pourra continuer ses publications importantes et sa collaboration internationale."

[15] "representa sempre um notável acontecimento, porque demonstra um intenso esforço colectivo da elite intelectual realizado com o fim de dar um largo desenvolvimento ao saber humano, e tornar possíveis mais descobertas, especulativas, de natureza a fornecerem ao espírito novas satisfações, ou de índole pratica, susceptiveis de contribuírem para que novos inventos melhorem as condições da vida da humanidade",

[16] "É dever de todos os povos precaverem-se e ligarem-se segundo as suas afinidades afim de evitarem, ou pelo menos atenuarem, tão horrorosos cataclismos".

Madrid (1913), Cadiz (1915), Sevilla (1917) and Bilbao (1919) but also worked towards a joint Portuguese-Spanish Congress. At his initiative the Associação Portuguesa para o Progresso das Sciencias (*Portuguese Association for the Advancement of Science*) was created in 1917 (Correia, 1922). The first joint Portuguese-Spanish Congress was held in Porto in 1921 (Bernardo, 2006). In a typical Costa Lobo manner, as a step was overcome, he was already thinking about the next one. In 1921, he proposed to include in future meetings the Latin American countries to which Spain and Portugal were bound by historical ties and friendly relations (Lobo, 1922). An ambitious idea which did not materialise.

Another example of Costa Lobo's motivation towards establishing international networks was the sharp increase of foreign mathematician members belonging to the Institute Association after Lobo attended the 1924 International Mathematical Congress (Ramos and Malonek, 2005; Costa and Malonek, 2006).

The solar observatory project provided the best opportunity to increase the internationalisation of Portuguese astronomy. The aim to continuously monitor the solar surface provides a clear argument for international collaboration. No Earth based observatory is able to uninterruptedly observe the Sun due to the rotation of the Earth. Consequently, several observatories at convenient longitudes are needed. Having more observatories also minimises the possibility of unfavourable weather at all observing locations.

At the initiative of George Ellery Hale (1868-1938) the National Academy of Sciences of the United States sent a circular asking various societies and academies to appoint committees for a meeting to be held in Saint-Louis in September 1904 to discuss a possible cooperation in solar studies. According to Hale it was unquestionable "that a science like our own cannot accomplish the most important advances without the collection of extensive data, beyond the reach of any individual or institution" (Hale, 1904, p. 310). At the meeting the delegates were:

> In favour of the organisation of a scheme of international co-operation in solar research, which shall encourage individual initiative, provide suggestions for definite lines of work, and facilitate the collection of results for publication. (Anonymous, 1904, p. 302)

Five conferences of the International Union for Solar Research were held between 1904 and 1913 (table 3).

Meeting	*Year*	*Held at*	*Date*
I	1904	St. Louis, USA	23 - 24 September
II	1905	Oxford, UK	27 - 29 September
III	1907	Meudon, France	20 - 23 May
IV	1910	Mount Wilson, USA	31 August - 2 September
V	1913	Bonn, Germany	30 July - 5 August

Table 3 - International Union for Solar Research Meetings

There were no Portuguese nationals in these gatherings. However, during the Bonn meeting, it was proposed that:

> the Observatories of Coimbra, Nice, and Starya Dubossary (Bessarabia), having now acquired spectroheliographs, should be added to our list, and that their directors, MM. da Costa Lobo, Chrétien, and Donitch, be invited to send delegates to our meetings. (Anonymous, 1914b, p. 97)

As a result, and despite his absence Costa Lobo was appointed to the "Photographic (using spectroheliograph, *enregistreur des vitesses*, spectrograph)" section of the Solar Atmosphere commission on account of Coimbra's future work. The commission members were "Hale (chairman); Chrétien, Cirera, Costa Lobo, Deslandres, Donitch, Evershed, Frost, Iñiguez, Kempf, W. J. Lockyer, Newall, Riccò, Slocum, St. John" (Slocum, 1913, p. 307).

The International Union for the Solar Research did not survive the First World War. After the war, the International Astronomical Union (IAU) was founded during the Constitutive Assembly of the International Research Council held from 18 to 28 July 1919 in Brussels. Since Portugal belonged to the War Allied Powers it was eligible for membership. For unknown reasons the country did not adhere immediately to the organisation. No Portuguese astronomers were present at the creation of the IAU, which may explain the delay in joining the union (AF, 1920). Neither were Portuguese delegates present at the first IAU General Assembly held in Rome in 1922 (Fowler, 1922). Nevertheless Costa Lobo attended the first meeting of the International Mathematical Union (IMU). As the Portuguese delegate he voted the IMU statutes (Ramos & Malonek, 2005). Lobo petitioned the government to join (Lobo, 1925b). In 1923, the government created the "Portuguese section of the International Astronomical, Geodesy and

Scientific Radiotelegraphic unions"[17] due to "the need to coordinate our astronomical, geodetic and radiotelegraphic services, so that [...] an easier collaboration with foreign similar services may ensue"[18] (Ministério de Instrução Pública, 1923). The positions of the section were to be filled by senior staff of relevant establishments and teachers from colleges where these issues were discussed. Costa Lobo was the first president of the section (Ministério de Instrução Pública, 1923).[19]

In 1924, Portugal officially joined the IAU. Table 4 summarises the portuguese participants in the general assemblies of the union held before the Second World War (Bonifácio, 2009, p. 355, and references therein).

Gen. A.	*Year*	*Held at*	*Portuguese participants*
I	1922	Roma, Italy	-
II	1925	Cambridge, United Kingdom	Costa Lobo, Francisco
III	1928	Leiden, Holland	Costa Lobo, Francisco
IV	1932	Cambridge, USA	Costa Lobo, Francisco
V	1935	Paris, France	Costa Lobo, Francisco Costa Lobo, Gumersindo
VI	1938	Stockholm, Sweden	-

Table 4 - Portuguese attendees at IAU General Assemblies held from 1922 to 1938

Unsurprisingly Francisco Costa Lobo and his son Gumersindo were responsible for all the Portuguese contributions mentioned in the General Assembly minutes during this period. However, the Costa Lobos were not the only Portuguese members of the IAU nor were they the only ones who belonged to the organisation committees (table 5) (Bonifácio, 2009, p. 357).

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[17] "Secção Portuguesa das Uniões Internacionais Astronómica, Geodésica e Radiotelegráfica Scientífica".

[18] "Atendendo à necessidade de coordenar os nossos serviços astronómicos, geodésicos e radiotelegráficos, de forma […] resulte uma maior facilidade de colaboração com serviços similares instalados nos outros países".

[19] The section had the following members: Honorary president, Rear Admiral Carlos Viegas Gago Coutinho; president, Astronomy professor and Coimbra University Astronomical Observatory director; Dr. Francisco Miranda of Costa Lobo; vice-presidents, Lisbon Astronomical Observatory director, Frederico Oom, and general administrator of Topographic and Geodetic Works, António Nogueira Mimoso Guerra; general secretary Monsanto's radiotelegraph station chief, Captain-Lieutenant Alvaro Augusto Nunes Ribeiro (Ministério de Instrução Pública, 1923).

At this time, we are unable to evaluate the work done by other members within their respective committees since preparatory meetings and exchange of correspondence took place outside general assemblies. We know, for example, that Francisco Costa Lobo attended the preparatory meeting of the 1932 General Assembly, in Paris in 1931. Still the general assembly transactions references to scientific works done by Portuguese astronomical observatories only mention the solar research done by Coimbra University Astronomical Observatory.

Date	*Member*		*Commission*
1925	Andrea, Eduardo	16	Observations physiques des planètes, des comètes, et des satellites
	Da Costa Lobo, F.	12	Physique Solaire
	Mimoso Guerra, A.	19	Variation des Latitudes
	Oom, F.	8	Astronomie Méridienne
	Ribeiro, A. N.	18	Longitudes par Télégraphie sans Fil
1928	Andrea, Eduardo	16	Observations physiques des planètes, des comètes, et des satellites
	Da Costa Lobo, F.	12 18	Physique Solaire Longitudes par Télégraphie sans Fil
	Oom, F.	8	Astronomie Méridienne
	Ribeiro, A. N.	31	Heure
	Rodrigues, J. C. S.	4	Ephémérides
1932	Da Costa Lobo, F.	11 18	Phénomènes Chromosphériques Longitudes par Télégraphie sans Fil
	De Lemos, V. H.	18	Longitudes par Télégraphie sans Fil
	Ribeiro, A. N.	31	Heure
1935	Andrea, Eduardo	16	Observations physiques des planètes, des comètes, et des satellites
	Da Costa Lobo, F.	4 11 13 18 m 19 m 31	Ephémérides Phénomènes Chromosphériques Éclipses solaires Longitudes par Télégraphie sans Fil Variation des Latitudes Heure
	Da Costa Lobo, G.	10	Taches solaires et des Figures caractéristiques solaires
	De Lemos, V. H.	18 m 31	Longitudes par Télégraphie sans Fil Heure
	Peres, M.	19	Variation des Latitudes

Table 5 - Portuguese belonging to IAU or mixed (m) IAU and IUGG commissions from 1922 to 1935. Election date of IAU commissions is also presented.

Conclusions

Historical research undoubtedly shows that the Portuguese scientists were aware of international developments in a variety of scientific branches including astronomy. Acting upon this knowledge and implementing up-to-date research programmes was, by contrast, a difficult and rarely successful task due to individual, institutional and material constraints. The attempt to pursue the new field of astrophysics in Portuguese observatories was held-up by astrometric activities until the 1920s. It took the initiative of Francisco Costa Lobo – assisted by, amongst others, Henri Deslandres and his son Gumersindo – to install a state of the art spectroheliograph and launch an observational solar physics programme in Coimbra.

Costa Lobo's will to install a solar research facility at Coimbra Observatory likely started in the early 1910s when he undertook several trips abroad. He visited foreign observatories, begun to attend international congresses and established personal contacts with various astronomers, including Henri Deslandres. The project to establish a symbiotic relationship between Meudon and Coimbra astronomical observatories based upon similar research objectives and instruments was particularly important. The expertise of Meudon Observatory facilitated the acquiring, testing, installing and fine-tuning of the Coimbra spectroheliograph. As soon as the instrument was operational the exchange of information was made easier and the data analysis more efficient. According to Deslandres, from "1925, the preparation will be easier since we have at our disposal the Coimbra photographs, sent regularly by the very active director of the observatory"[20] (Deslandres, 1928, p. 28). It is worth stressing that Costa Lobo was at the time a 64-year-old man. One should also point out that other observatories such as Madrid Observatory opted to have their own spectroheliograph model. The solar physics section of Coimbra Astronomical Observatory had a clearly defined research programme and the observation results were regularly published from 1932 onwards.

Both the astronomers involved and the Portuguese and French governments valued Coimbra-Meudon co-operation. Azambuja travelling at the expense of the French government is a good example of this. Other pieces of evidence were provided by the attribution of honorific titles and prizes to those who were active in the process. Costa Lobo received the *Académie des Sciences de Paris* Janssen prize, on 13 December 1926, for his astronomical works (Anonymous, 1927a, 1927b, 1927c). Deslandres and

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[20] "À partir de 1925, la préparation sera plus facile ; car nous aurons à notre disposition les épreuves de Coïmbra, envoyées régulièrement par le très actif directeur de l'Observatoire, le professeur da Costa Lobo."

Azambuja were awarded the Sant'iago da Espada military order by the Portuguese government in 1920 and 1929, respectively. The order distinguished literary, scientific and artistic merit (Presidência da República Portuguesa).

As we have seen, the Coimbra spectroheliograph opened a door within the International Union for cooperation in Solar Research and likely the IAU. Initially, Costa Lobo was the only beneficiary of this situation but others followed him. In fact, we suspect that Lobo had an instrumental role in putting other Portuguese astronomers in several IAU committees. Costa Lobo, as a committed internationalist, participated in other collaborative events such as the wireless longitude determination in 1933 and organised several international congresses (Stratton, 1946).

What the documents lead us to conclude is that despite bureaucratic, institutional and personal difficulties Costa Lobo – helped by a network of friends which he created, cherished and maintained – managed to put his plan into practice. A new world-class solar facility was built and observations were made, shared and published. Its astronomers collaborated with foreign colleagues and attended international conferences as equals. Costa Lobo's strategy created not only a long-standing international partnership with Meudon Observatory but also managed to take Portuguese astronomy out of its seclusion.

References

A.F. (1920), "The international Astronomical Union", *Monthly Notices of the Royal Astronomical Society*, vol. 80, Issue 4, 9 February, p. 433-435.

AMORIM Diogo Pacheco de (1955), "Elogio Histórico dos doutores Francisco de Miranda da Costa Lobo e Gumersindo Sarmento da Costa Lobo", *O Instituto*, vol. 117, p. 1-29.

ANONYMOUS (1904), "International Co-Operation in Solar Research", *Astrophysical Journal*, vol. 20, p. 301-305.

ANONYMOUS (1914a), "Part II - List of Delegates", *Transactions of the International Union for Cooperation in Solar Research*, vol. 4, p. 5-8.

ANONYMOUS (1914b), "Part III - Proceedings - Fifth Conference", *Transactions of the International Union for Cooperation in Solar Research*, vol. 4, p. 9-168.

ANONYMOUS (1914c), "Part IV - Resolutions Adopted", *Transactions of the International Union for Cooperation in Solar Research*, vol. 4, p. 169-174.

ANONYMOUS (1916), "Actas de las sesiones celebradas por la sección de ciencias matemáticas, del congreso de Valladolid", in ASOCIACIÓN

ESPAÑOLA PARA EL PROGRESSO DE LAS CIENCIAS (ed.), *Congreso de Valladolid*, Madrid, Imprenta de Fortanet, p. 25-28.

ANONYMOUS (1922), "Proposta de lei nº272", *Diario do Senado*, 2 de Setembro, p. 23.

ANONYMOUS (1925), "Notícia do Congresso de Coimbra", *O Instituto*, vol. 72, p. 508-513.

ANONYMOUS (1927a), "General Notes", *Publications of the Astronomical Society of the Pacific*, vol. 39, p. 137-141.

ANONYMOUS (1927b), "Notes", *The Observatory*, vol. 50, p. 60-68.

ANONYMOUS (1927c), "Prix de l'Académie des Sciences", *Bulletin de la Société Astronomique de France et Revue Mensuelle d'Astronomie Populaire*, *de Météorologie et de Physique du Globe*, vol. 48, p. 90-91.

BERNADO Liliana L. (2006), *O Primeiro Congresso Português para o Progresso das Ciências*, Master Thesis, Universidade de Aveiro, Online: http://hdl.handle.net/10773/2887

BONIFÁCIO Vitor (2009), *Da Astronomia à Astrofísica: A perspectiva portuguesa*, Ph .D. Thesis, Universidade de Aveiro. Online: http://hdl.handle.net/ 10773/4837.

BONIFÁCIO Vitor, MALAQUIAS Isabel & FERNANDES João (2007), "Solar Photography in the Nineteenth Century: the Case of the Infante D. Luiz Observatory in Lisbon (1871-1880)", *Journal of Astronomical History and Heritage*, vol. 10, p. 101-113.

BONIFÁCIO Vitor, MALAQUIAS Isabel & FERNANDES João (2009), "Taking Internal Advantage of External Events - Two Astronomical Examples From Nineteenth Century Portugal", *Centaurus*, vol. 51, p. 213-234.

BONIFÁCIO Vitor, MALAQUIAS Isabel & FERNANDES João (2010), "The first astronomical hypothesis based upon cinematographical observations: Costa Lobo's 1912 evidence for polar flatenning of the Moon", *Journal of Astronomical History and Heritage*, vol. 13, p. 159-168.

COMAS SOLÁ José (1917), "El Congreso de Ciencias en Sevilla", *La Vanguardia*, 16 de Mayo, p. 8.

COMMISSION INTERNATIONAL D'AGRICULTURE (1912), *IX*[e] *Congrès international d'agriculture,* Madrid, Imprenta de Bernardo Rodríguez, p. 34.

COMMISSION 12 (PHYSIQUE SOLAIRE) (1933), "Résolutions adoptées", in Frederick J. M. STRATTON (ed.), *Transactions of the International Astronomical Union. Fourth General Assembly held at Cambridge, Massachusetts*, Cambridge (MA), Cambridge University Press, p. 283.

CORREIA António A. Mendes (1922), "Notícia pelo secretário geral", in ASSOCIAÇÃO PORTUGUESA PARA O PROGRESSO DA SCIÊNCIAS (ed.), *Primeiro congresso: celebrado na cidade do Pôrto de 26 de Junho a 1 de Julho de 1921 juntamente com o oitavo congreso da Associação Espanhola para o Progresso* *das Sciências. Sessões plenárias*, Coimbra, Imprensa da Universidade, p. 5-14.

COSTA Teresa & MALONEK Helmuth (2001), "Uma iniciativa notável de Costa Lobo (Anotações sobre oportunidades que Portugal não aproveitou", *HELIOS. Electronic Journal published by the Observatório Astronómico da Universidade de Coimbra*, vol. 7, Online: http://www.mat.uc.pt/~helios/Mestre/Janeir01/H71clobo.htm

DESLANDRES Henri (1909), "Sur une solution générale du spectrohéliographe", *Comptes rendus hebdomadaires des séances de l'Académie des sciences*, vol. 148, p. 968-974.

DESLANDRES Henri (1922), *Rapport sur l'observatoire d'astronomie physique de Meudon. Année 1921*, Paris, Gauthier-Villars.

DESLANDRES Henri (1927), *Rapport Annuel sur l'État de l'Observatoire de Paris pour l'Année 1926*, Paris, Gauthier-Villars.

DESLANDRES Henri (1928), *Rapport Annuel sur l'État de l'Observatoire de Paris pour l'Année 1927*, Paris, Gauthier-Villars.

ESCLANGON Ernest (1929), *Rapport Annuel sur l'État de l'Observatoire de Paris pour l'Année 1928*, Paris, Gauthier-Villars.

ESCLANGON Ernest (1930), *Rapport Annuel sur l'État de l'Observatoire de Paris pour l'Année 1929*, Paris, Gauthier-Villars.

ESCLANGON Ernest (1931), *Rapport Annuel sur l'État de l'Observatoire de Paris pour l'Année 1930*, Paris, Gauthier-Villars.

ESCLANGON Ernest (1932), *Rapport Annuel sur l'État de l'Observatoire de Paris pour l'Année 1931*, Paris, Gauthier-Villars.

ESCLANGON Ernest (1933), *Rapport Annuel sur l'État de l'Observatoire de Paris pour l'Année 1932*, Paris, Gauthier-Villars.

ESCLANGON Ernest (1934), *Rapport Annuel sur l'État de l'Observatoire de Paris pour l'Année 1933*, Paris, Gauthier-Villars.

ESCLANGON Ernest (1935), *Rapport Annuel sur l'État de l'Observatoire de Paris pour l'Année 1934*, Paris, Gauthier-Villars.

FERREIRA António V. & MACHADO António Ginestal (1921), *Diario da Câmara dos Deputados*, 5 de Setembro, p. 36.

FOWLER A. (ed.) (1922), *Transactions of the International Astronomical Union. First General Assembly held at Rome*, London, Imperial College Bookstall.

GARRIDO S. J. Ricardo (1912), "El estudio espectral de las manchas de sol", in ASOCIACIÓN ESPAÑOLA PARA EL PROGRESSO DE LAS CIENCIAS (ed.), *Congresso de Granada, Tomo III. Astronomía y Física del Globo*, Madrid, Imprenta de Eduardo Arias, p. 73-92.

GINGERICH Owen (ed.) (2010), *General history of astronomy*, *Volume 4A. Astrophysics and Twentieth century Astronomy to 1950*, Cambridge (UK), Cambridge University Press (2nd edition).

HALE George E. (1904), "Co-operation in Solar Research", *Astrophysical Journal*, vol. 20, p. 306-312.
HEARNSHAW John B. (1986), *The Analysis of Starlight. One Hundred and Fifty Years of Astronomical Spectroscopy*, Cambridge (UK), Cambridge University Press.
HEARNSHAW John B. (1996), *The Measurement of Starlight. Two Centuries of Astronomical Photometry*, Cambridge (UK), Cambridge University Press.
HEARNSHAW John B. (2009), *Astronomical Spectrographs and their History*, Cambridge (UK), Cambridge University Press.
HERRMANN Dieter B. (1984), *The History of Astronomy from Herschel to Hertzsprung*, Cambridge (UK), Cambridge University Press.
IÑÍGUEZ Francisco & ASCARZA Victoriano F. (1912), "El nuevo espectroheliógrafo del Observatorio de Madrid", in ASOCIACIÓN ESPAÑOLA PARA EL PROGRESSO DE LAS CIENCIAS (ed.), *Congresso de Granada, Tomo III. Astronomía y Física del Globo*, Madrid, Imprenta de Eduardo Arias, p. 133-142.
KIRCHHOFF Gustav (1860), "On the Simultaneous Emission and Absorption of Rays of the same definitive Refrangibility", *London, Edinburgh and Dublin philosophical magazine and journal of science*, ser. 4, vol. 19, p. 195-196.
LEAL Ernesto Castro (1998), "A Cruzada Nacional D. Nuno Álvares Pereira e as origens do Estado Novo (1918-1938)", *Análise Social*, vol. 33, p. 823-851.
LOBO Francisco da Costa (1912a), "As radiações e a atração newtoniana", in ASOCIACIÓN ESPAÑOLA PARA EL PROGRESSO DE LAS CIENCIAS (ed.), *Congresso de Granada*, *Tomo III. Astronomía y Física del Globo*, Madrid, Imprenta de Eduardo Arias, p. 25-28.
LOBO Francisco da Costa (1912b), "Determinação do azimuth dos instrumentos meridianos", in ASOCIACIÓN ESPAÑOLA PARA EL PROGRESSO DE LAS CIENCIAS (ed.), *Congresso de Granada*, *Tomo III. Astronomía y Física del Globo*, Madrid, Imprenta de Eduardo Arias, p. 29-34.
LOBO Francisco da Costa (1912c), "Enregistrement cinématographique de l'éclipse du 17 avril, et forme un peu allongée du contour lunaire", *Comptes rendus hebdomadaires des séances de l'Académie des sciences*, vol. 154, p. 1396-1399.
LOBO Francisco da Costa (1912d), "L'éclipse de soleil du 17 avril 1912", *Revista da Universidade de Coimbra*, vol. 1, p. 548-585.
LOBO Francisco da Costa (1922), "Alocução proferida por F. M. da Costa Lobo, Presidente do Instituto de Coimbra", in ASSOCIAÇÃO PORTUGUESA PARA O PROGRESSO DAS SCIÊNCIAS (ed.), *Primeiro*

congresso: celebrado na cidade do Pôrto de 26 de Junho a 1 de Julho de 1921 juntamente com o oitavo congreso da Associação Espanhola para o Progresso das Sciência. Sessões plenarias, Coimbra, Imprensa da Universidade, p. 166-170.

LOBO Francisco da Costa (1925a), "A Astronomia em Portugal na actualidade", in ASOCIACIÓN ESPAÑOLA PARA EL PROGRESSO DE LAS CIENCIAS (ed.), *Congresso de Coimbra, Tomo I*, Madrid, Talleres Poligráficos.

LOBO Francisco da Costa (1925b), *Les nouveaux instruments spectrographiques*, Coimbra, Imprensa da Universidade.

LOBO Francisco da Costa (1926), "Correlation entre les protubérances et les filaments solaires. Agitation de la surface des facules", *Comptes rendus hebdomadaires des séances de l'Académie des sciences*, vol. 183, p. 188-189.

LOBO Francisco da Costa (1927), "Sur deux protubérances intéressantes", *Comptes rendus hebdomadaires des séances de l'Académie des sciences*, vol. 184, p. 75-76.

LOBO Francisco da Costa (1929), "Nouveau mode de représentation des couches sphériques solaires", *Comptes rendus hebdomadaires des séances de l'Académie des sciences*, vol. 189, p. 277-278.

LOBO Francisco da Costa (1932a), "Introdução", *Anais do Observatório Astronómico da Universidade de Coimbra - Primeira Secção - Fenómenos Solares*, vol. 1, p. 7-16.

LOBO Francisco da Costa (1932b), *Anais do Observatório Astronómico da Universidade de Coimbra - Primeira Secção - Fenómenos Solares*, vol. 1, Coimbra, Imprensa da Universidade.

LOBO Francisco da Costa (1932c), "Relatórios apresentados pelo director da Faculdade de Ciências F. M. da Costa Lôbo relativos aos anos de 1930-31, 1931-32, 1932-33", *Revista da Faculdade de Ciências*, vol. 4, p. 141-160.

LOBO Gumersindo da Costa (1940), *A criação dos estudos de astrofísica em Portugal com a instalação da secção de astrofísica no Observatório astronómico da Universidade de Coimbra*, Coimbra, Coimbra Editora.

LOBO Gumersindo da Costa (1944), *A caracterização dos fenómenos solares e a sua classificação*, Associação Portuguesa para o Progresso das Ciências, Porto, Emprêsa Industrial Gráfica do Porto.

LÓPEZ ARROYO Manuel (2004), *El Real Observatorio Astronómico de Madrid (1785-1975)*, Madrid, Dirección General del Instituto Geográfico Nacional.

MALTEZ José A. (2005), *Tradição e Revolução. Uma biografia do Portugal Político so século XIX ao XXI*, *Volume 2. 1910-2005*, Lisboa, Tribuna da História.

MATA Eugénia & VALÉRIO Nuno (2003), *História Económica de Portugal uma perspectiva global*, Queluz de Baixo, Editorial Presença (2nd edition).

MEADOWS Arthur Jack (1970), *Early Solar Physics*, Oxford, Pergamon Press.
MINISTÉRIO DE INSTRUÇÃO PÚBLICA (1922), "Lei nº1377, 23 de Setembro", *Diário do Govêrno*, n°1036.
MINISTÉRIO DE INSTRUÇÃO PÚBLICA (1923), "Decreto nº9:109 de 7 de Setembro", *Diário do Govêrno*, n°193.
MÓNICA Maria Filomena (ed.) (2004), *Dicionário biográfico parlamentar: 1834-1910, vol. II (D - M)*, Lisboa, Assembleia da República e Imprensa de Ciências Sociais.
MOURADIAN Zadig & GARCIA Adriana (2007), "Eightieth Anniversary of Solar Physics at Coimbra", in Petr HEINZEL, Ivan DOROTOVIC & Robert J. RUTTEN (eds.), *The Physics of Chromospheric Plasmas*, San Francisco, Astronomical Society of the Pacific, p. 3-14.
OOM Frederico (1905), "O Futuro Eclipse", *O Instituto*, vol. 52, p. 487-490.
PORTUGAL (1907), *Diário da Câmara dos Deputados*, Lisboa, Imprensa Nacional.
PRESIDÊNCIA DA REPÚBLICA PORTUGUESA, "Ordens Honoríficas Portuguesas", Online: http://www.ordens.presidencia.pt, consulted on 24 April 2017.
RAMOS Anabela & MALONEK Helmuth R. (2005), "Portugal e a fundação da União Matemática Internacional", *Gazeta de Matemática*, vol. 148, p. 12-17.
RAPOSO Pedro (2010), *Polity, precision and the stellar heavens: the Royal Astronomical Observatory of Lisbon (1857-1910)*, Ph.D. Thesis, University of Oxford.
REMÉDIOS Joaquim Mendes dos (1912), "A Universidade de Coimbra perante a Nova Reforma dos Estudos", *Revista da Universidade de Coimbra*, vol. 1, p. 589-622.
REPÚBLICA PORTUGUESA (1922), "Lei nº1:377, 23 de Setembro" *Diário do Govêrno*, ser. 1, vol. 199, p. 1036.
RODRIGUES Manuel A. (1992), *Memoria Professorum Universitatis Conimbrigensis: 1772-1937*, Coimbra, Arquivo da Universidade de Coimbra.
RUIZ-CASTELL Pedro (2008), *Astronomy and Astrophysics in Spain (1850-1914)*, Cambridge (UK), Cambridge Scholars Publishing.
SILVA A. Simões da (1969), "Sobre a reinstalação do espectroheliógrafo", *O Instituto*, vol. 131, p. 229-235.
SILVA Manuel José da (1921), *Diario da Câmara dos Deputados*, 6 de Maio, p. 10.
SLOCUM Frederick (1913), "The International Union for Co-operation in Solar Research", *Astrophysical Journal*, vol. 38, p. 301-310.

STRATTON Frederick J. M. (ed.) (1929), *Transactions of the International Astronomical Union. Third General Assembly held at Leiden*, Cambridge (UK), Cambridge University Press.

STRATTON Frederick J. M. (1946), "Obituary Notices: da Costa Lôbo, Francisco Miranda", *Monthly Notes of the Royal Astronomical Society*, vol. 106, p. 41.

UNIVERSIDADE DE COIMBRA (1888), *Annuario da Universidade de Coimbra. Anno Lectivo de 1887-1888*, Coimbra, Imprensa da Universidade.

UNIVERSIDADE DE COIMBRA (1894), *Annuario da Universidade de Coimbra. Anno Lectivo de 1893-1894*, Coimbra, Imprensa da Universidade.

UNIVERSIDADE DE COIMBRA (1904), *Annuario da Universidade de Coimbra. Anno Lectivo de 1904-1905*, Coimbra, Imprensa da Universidade.