The beginning of astrophysics in Portugal

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Abstract The year 1870 marks a turning point in the development of Portuguese astronomy. Prior to this date no national expertise existed in the field of astronomical spectroscopy. On hindsight one realises the change catalyst was provided by the total solar eclipse of 1870 December 22, observable from Portugal. Wishing to perform useful observations the Portuguese scientific community sought advice from their international counterparts and with government support acquired new instruments and organised an eclipse expedition to the Algarve. Poor weather prevented a successful observation but in the expedition aftermath the acquired instruments were distributed to the Infante D. Luiz and Tapada da Ajuda observatories and the faculties of Mathematics and Philosophy of Coimbra University. As a consequence several of these institutions attempted, in the following years, to start-up astrophysical studies albeit with different degrees of success. In particular the Infante D. Luiz Observatory solar photography programme produced first-class results internationally recognised.

During the 1870's a new teaching/research astronomical observatory was built at the Lisbon Polytechnic School. Strategically, it was decided that the new establishment should concentrate on astrophysical research and astronomical photography. In the end the instruments acquired were below initial expectations and, in particular, the 11-inch photographic Alvan Clark & Sons telescope never arrived in Lisbon. As a consequence the observatory became a teaching facility.

By the end of the 1870's all Portuguese astrophysical research initiatives had either failed or terminated. Only in the second decade of the 20th century efforts were, once more, made to pursue astrophysical studies in Portugal. In this article we will review the earlier 19th century initiatives and discuss their outcomes.

Keywords: Astrophysics, Astronomical Photography, Development, Portugal

1. The beginning of astrophysics

The explanation of the solar spectra dark divisions, today called absorption lines, discovered by William Wollaston (1766–1828) in 1802 and extensively mapped by Joseph Fraunhofer (1787–1826) in the 1810's was put forward by Gustav Kirchhoff (1824–1887) in a communication to the Berlin Academy dated 20 October 1859 and read 7 days later. Passing solar radiation through a flame coloured with table salt Kirchhoff observed that the Fraunhofer D lines of the solar spectrum did not weakened as expected but got darker instead. This prompted Kirchhoff to conclude that

> the dark lines of the solar spectrum which are not evoked by the atmosphere of the earth, exist in consequence of the presence, in the incandescent atmosphere of the sun, of those substances which in the

spectrum of a flame produce bright lines at the same place [Kirchhoff, 1860].

Consequently sodium was present in the solar atmosphere. Kirchhoff's breakthrough allowed one to use a familiar instrument, the spectroscope, to acquire information about the constitution and physical properties of celestial bodies. Before a decade had elapsed

- several elements, amongst them calcium and iron, were confirmed in the solar atmosphere;
- new solar atlas were published by Kirchoff and Anders Ångström (1814–1874);
- atmospheric water vapour was identified as the culprit of several absorption lines;
- the first stellar spectral classification was proposed, in 1863, by Angelo Secchi (1818–1878);
- it was realised that nebulae had two different spectral signatures, i. e., had different constitutions, and were either star agglomerates or masses of luminous gas or vapour;
- a 'new' atomic element, Helium, was discovered in the solar atmosphere in 1868.

In 1865, Johann Zöllner (1834–1882) coined the word astrophysics to designate this new type of astronomical research that allowed one to obtain information about the nature of the celestial bodies [Zöllner, 1865].

2 An opportunity - the 22 December 1870 total solar eclipse

No astrophysical research was performed in Portugal during the 1860's a likely consequence of the country astronomical infrastructure at the time.

There were three astronomical observatories in Portugal in 1870. The Coimbra University Observatory was established in 1772 by Pombal's University reform as part of the Faculty of Mathematics. Located at the University campus in a cramped 18th century edifice the observatory mainly focused on maintaining the publication of the Coimbra Ephemeris following an 1850's failed attempt to acquire competitive astrometric instruments and construct a new building [Bonifácio, 2009]. The Lisbon Navy Observatory was poorly located on the Tagus riverbank and following the March 1858 earthquake part of the building was in risk of collapsing. The construction of a new Lisbon observatory began in 1861 after a long and tortuous process. Built with the advice and support of, amongst others, Wilhelm Struve (1793–

1864) the Tapada da Ajuda observatory tried to emulate Pulkovo observatory, arguably the world's best, albeit in a better climate. Its main research goal was to be high precision stellar measurements [Bonifácio, Malaquias, and Fernandes, 2009; Raposo, 2006]. In 1870, construction was still underway, in particular and the observatory had no statutes [Folque, 1872].

In summary, in 1870, all Portuguese astronomical observatories pursued astrometric goals. Nevertheless the new spectroscopic developments were known and had already entered the course curricula of, at least, the Coimbra University and Lisbon Polytechnic School [Gomes and Malaquias, 2006; Gomes, 2007][1]. Following the 1861 curricula reform the students of mathematics were obliged to attend three physics courses at the Faculty of Philosophy and as a consequence come into contact with spectroscopic studies. Alfredo Filgueiras da Rocha Peixoto (1848–1904) *Dissertação Inaugural* (doctorate essay) presented in 1870 is the earliest reference to astronomical spectroscopy by a student of mathematics we found. According to Peixoto the newest period in the history of astronomy, "physicochemical astronomy", was "opened up by the wonderful discovery of Kirchoff and Bunsen". The essay also discusses recent developments in solar and stellar spectroscopy [Peixoto, 1870].

In the 19th century the occurrence of a total solar total eclipse could be predicted several decades in advance. For example François Arago (1786–1853) mentions the 1870 December 22 total solar eclipse in an 1845 publication [Arago, 1845; p. 272]. The Coimbra Astronomical Observatory Ephemeris for the year 1870, published in 1868, communicated that the solar eclipse of December 22 would be "total in the South of Portugal" and local eclipse circumstances were calculated for five Portuguese towns, Coimbra, Lisboa, Monchique, Loulé and Tavira [Universidade de Coimbra, 1868]. Furthermore in order to better determine the lunar shadow limits at the Earth's surface and the eclipse central line Rodrigo Ribeiro de Sousa Pinto (1811–1893), the observatory director, improved the formulae previously used by the Coimbra ephemeris calculators [Pinto, 1868].

Not surprisingly the earliest push for an eclipse expedition occurred at a Coimbra University Faculty of Mathematics congregation. On 27 October 1869 the topic was discussed and an eclipse planning commission composed of the faculty director and

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[1] In 1870 there were the following higher instruction institutions in Portugal: Coimbra University, Lisbon Polytechnic School, Porto Polytechnic Academy, Medico-Surgical Schools of Lisbon, Porto and Funchal, Lisbon Higher Literary Course (Curso Superior de Letras) and Lisbon Military School.

the Practical Astronomy and Celestial Mechanics professors was appointed [Bonifácio, 2009; Bonifácio, Malaquias, and Fernandes, 2006a; and references therein]. At the time the observatory director was barred from attending the monthly faculty congregations. In this odd arrangement the University Rector, Júlio Máximo de Oliveira Pimentel (1809–1884), asked Sousa Pinto's opinion on the subject. In early November professors of the Faculty of Philosophy became unofficially involved in the planning process. Advice was sought from foreign experts, amongst them Balfour Stewart (1828–1887) and Angelo Secchi [Freire, 1872]. On November 15 the University Rector sent Sousa Pinto's answer to the General Direction of Public Instruction. On the 25, he was ordered to appoint a new commission under his presidency composed of an underdetermined number of Philosophy and Mathematics Faculty members plus the directors of the University Observatories [Secretaria Geral do Ministério do Reino; p. 214].

On 15 January 1870, the Rector forwarded the commission eclipse expedition blueprint to the government. The 5:000$000 réis budget considered a three person exploratory trip to Algarve to determine the best location of the observing station(s), the establishment of an observing camp for a party of twelve and 3:900$000 réis for the acquisition of new instruments. Although the report states that it would be desirable to have a second observing station the commission did not insist on the idea presumably because the extra instruments and manpower would increase the already substantial budget [Pimentel, 1870].

In the meantime Filippe Folque (1800–1874), director of the Lisbon Navy Astronomical Observatory, aware of these efforts, suggested in a November 27 letter to the Navy and War Minister[2] that an eclipse planning commission composed of the directors of the Portuguese Astronomical and Meteorological Observatories should be appointed. On the 24th the government apparently following Folque's suggestion appointed a commission composed of the directors of the University Meteorological and Astronomical Observatories, the Navy Astronomical Observatory and the Lisbon Polytechnic School Meteorological Observatory. This commission was required to report the measures that should be taken to observe the solar eclipse in the conditions required by science. On February 4 it became necessary to replace the Lisbon

2 In the United Kingdom this position is called Secretary of State.

Polytechnic School Observatory representative by the interim director João Carlos de Brito Capello (1831–1901).

On February 7 the commission presented to the government an expedition budget, asked permission to order new instruments and recommended that the expedition members should be nominated as soon as possible. On the following day the government appointed a new six strong commission to carry out the work required to observe the eclipse. With the inclusion of Frederico Augusto Oom (1830–1890) from the Tapada da Ajuda Astronomical Observatory all astronomical and meteorological Portuguese observatories were now represented on the commission and as such the eclipse endeavor truly became a national one. The government decree also authorised the commission to request, safeguarding normal service necessities, any necessary instruments from any scientific establishment responding to the Kingdom ministry.

Important strategic decisions were taken at the new commission first meeting on February 18. It was decided to acquire from Repsold three clockwork driven equatorial telescopes with Merz optics, a Steinhel photoheliograph similar to the one used by the 1869 German eclipse expedition to Aden and two Hofmann direct vision spectroscopes. The scientific programme included solar photography, spectral observations, measurement of solar protuberances positions and dimensions, drawings of the corona, timing the instants of contact and meteorological observations. Conceptually the research programme was similar to that of other eclipse expeditions elsewhere [Pang, 2002]. On March 3 the expedition party was increased to 11 members.

In May a small party when to Algarve to study possible observing stations. The small town of Tavira was chosen due to its location near the eclipse central line and the fact that it was connected to Lisbon both by a regular shipping line and by the telegraph. In particular, the latter allowed a fast and precise determination of the observers' longitude by the telegraphic method. The commission planned to distribute a circular, written in French, accompanied by a map of the eclipse path in Portugal to entice foreign astronomers to establish observing stations in the country. Lacking a government reply the commission decided instead to send the map to foreign observatories, astronomers and astronomical societies. This was the only commission request that failed to get a speedy government decision, which is remarkable in the context of the country political instability. In 1870 there was a military coup (May 19), two general elections (March 13 and September 18) and four governments.

Following the military coup the government organisation was changed and the responsibility of the country education and, inherently, the eclipse expedition moved from the Kingdom Ministry to a new Instruction Ministry that lasted between June 22 and August 29.

Events abroad had a larger impact upon the expedition. As a consequence of the Franco-Prussian War (19 July 1870–10 May 1871) the instrument maker Hoffmann fled Paris and was unable to deliver the direct vision spectroscopes. Acting swiftly Folque, the commission president, ordered two replacement instruments from Merz. Nevertheless predicting the possibility that these were not delivered on time a makeshift spectroscope was made at the Lisbon Industrial Institute. One Merz spectroscope arrived in Tavira the day before the eclipse while the other one was shipped to Brazil by mistake.

In the meantime recognising that the lack of practical experience could hinder the 'new' observations the government agreed, on August 1, to send Antonio dos Santos Viegas (1837–1914) in a study trip abroad. In Rome he had the opportunity of practise under two of the leading solar researchers of the day Lorenzo Respighi (1824–1889) and Angelo Secchi. In November both Sousa Pinto and Jacintho de Souza (1818–1880) left the commission for unknown reasons but probably related with the power struggle taking place within the University Faculty of Mathematics and discussed in section 3.3 below. Two other Coimbra University professors hastily replaced them as expedition members.

On the days preceding the eclipse solar photographs were taken. On the 21 December Viegas observed the solar protuberances with the spectrograph and drew the results. On the 22 everything was prepared for the eclipse observation when the unpredictable December weather thwarted the effort put into the expedition. It was raining when the moon's shadow passed Tavira. Bad weather troubled other observing stations located in or around the Mediterranean. Still some interesting results were obtained. In Italy the green coronal emission line first seen at the 1869 eclipse was confirmed [Santini, 1872]. In Spain, Charles Young (1834–1908) observed for the first time the spectral line reversal that occurs near a total solar eclipse 2nd and 3rd contacts as the Moon covers and uncovers the solar surface, respectively [Langley, 1871]. The comparison of the photographs taken in Sicily and Spain gave further support for the corona being a solar structure [Brothers, 1871].

3 In the eclipse aftermath

At the commission last meeting, on December 30, it was unanimously decided to press upon the government the need to distribute the new instruments amongst the Coimbra University, the Tapada da Ajuda Astronomical Observatory and the Infante D. Luiz Meteorologic Observatory so that the studies already started may be continued. A suggestion sent to the government on 2 January 1871.

3.1 A strategic decision

Possibly reflecting the unease that led to Sousa Pinto and Jacintho de Souza leaving the expedition the commission proposed that the instruments delivered to the "Faculty of Philosophy would be deposited in the physics cabinet for the use of the optics professor" and those destined for the "Faculty of Mathematics would be deposited at the Coimbra Astronomical Observatory for the use of the professor of Practical Astronomy". That is the instruments were earmarked for Santos Viegas and Luiz Albano Moraes e Almeida (1819–1888), respectively [Folque, 1871]. On a 4 January 1871 decree the government decided instead that

- the telescope number one, with the Merz spectroscope is intended for the Coimbra University Faculty of Philosophy
- the telescope number two, with the other spectroscope is intended for the Royal Astronomical Observatory at Tapada
- the telescope number three, with the spectroscope ordered from Hofman [sic.], for the Infante D. Luiz Observatory
- the telescope number four [the photoheliograph], and all its accessories with the other spectroscope ordered from Hofman [sic.] to the Coimbra University Faculty of Mathematics.

Clearly the decree avoided a potential controversy by removing the reference to specific University courses and professors. In practice this allowed the Mathematical and Philosophy faculties to used the instruments in any way they saw fit. It is worth noting that the decree was rather vague concerning research objectives. The distribution of instruments was made so that "the studies to which they were destined" could continue [Ministério do Reino, 1871]. Importantly there was for the first time the possibility to start-up astrophysical studies in Portugal.

3.2 Lost opportunities

The Tapada da Ajuda observatory project was focused on precision astrometry. A goal confirmed by the first observatory statutes approved in 1878. We are not aware of any astrophysical studies done at the observatory during the 19th century.

In 1860 several steps were taken to provide Coimbra University with a Magnetic and Meteorological Observatory belonging to the Faculty of Philosophy. At the time solar studies and, in particular, a possible solar influence on the earth were considered part of the duties of magnetic and meteorological observatories. In a report written after his second visit to Kew in 1861, Jacintho de Souza specifically refers the sunspot photographs taken with the observatory photoheliograph. However due to the its cost and since instrumental improvements were expected to the novel design the photoheliograph acquisition was postponed [Souza, 1862; p. 75]. The first meteorological observations were obtained with the observatory still under construction in February 1864. From July 1866 magnetic inclination and horizontal force were measured regularly while the measurements of magnetic declination began in 1867 [Souza, 1872; p. 196].

On 13 January 1870 the Faculty of Philosophy congregation decided that "in order to begin spectrometry work" the instruments were assigned to Santos Viegas [Carvalho, 1872; p. 174]. On 5 March 1872, Jacintho de Souza, the observatory director, claimed the instruments "would make sunspots observations and solar and planetary spectrometry" when the rotating dome was completed [Real, Rocha and Castro, 1872; p. 233]. In November the University rector asked the observatory director to prepare a distribution of service compatible with the study of the "physical constitution of the sun" and to indicate the remuneration to be assigned to the different employees [Pimentel, 1876; 26 November 1872]. In the begin of January 1873 the Merz telescope was finally placed under the observatory dome and the Rector wrote to the government requesting Santos Viegas inclusion in the observatory staff. This implied an observatory budget increase of 124$000 réis (7%). The rector argued with Viegas expertise and the importance of the study of "of solar protuberances and, in general, the physical constitution of the sun, the celestial bodies spectral analyses [...] for from them depends the solution of the highest cosmological problems", to no avail [Pimentel, 1876; 3 January 1873]. In an 1878 written description of the observatory Jacintho de Souza refers the existence of the Merz refractor installed under the dome of the main building but does not indicate any observations made with it. This contrasts with the detailed description of the magnetic instruments, their operation and even the data analysis performed at the observatory. The same report indicated the different tasks assigned to the observatory assistants and all of these corresponded to either magnetic or meteorological observations [Pimentel, 1878]. On the other hand we know that Santos Viegas only joined the observatory staff on 1880 August 25 after being appointed director following Jacintho de Souza's death. An appointment that apparently did not changed the lack of astrophysical studies at the observatory since, once more, none is referred in an 1892 report [Lopes, 1892].

In summary, we conclude that although the implementation of astrophysical studies has been cherished from the planning stage of the Coimbra University Magnetic and Meteorological Observatory, in practice, they were not implemented during the 19th century.

3.3 Power struggle at the Coimbra Astronomical Observatory

Following the failed 1850s attempt to replace the 18th century observatory building and acquire competitive instruments Sousa Pinto re-focused, in the 1860s, the institution workload on improving the Coimbra Astronomical Ephemeris. The publication was started in 1803 with the astronomical predictions for the following year and its original approach led to a very positive international reception [Bonifácio, 2009]. In 1840 failing to incorporate the new astronomical tables the ephemeris was outdated. In the following years an effort was made to renew the publication but in the 1850's their advancement decreased. A crisis point was reached when the Ephemeris for the year 1861 was published in 1861 greatly reducing its potential use. That year new interim regulations were defined and in the next decade both of these problems were dealt with mainly due to the leadership of Sousa Pinto initially as the observatory interim director and from 1866 onwards as the director.

As the 1860s progressed several problems, some interlinked, became apparent:

- Sousa Pinto ruled the observatory with an 'iron fist' while pursuing his life long interest in astrometry;
- other observatory astronomers wanted to try out the 'new' spectroscopical and photographic techniques;

- the ephemeris calculation used the majority of the observatory human and budgetary resources for no apparent reason since the Portuguese Navy relied on the *Nautical Almanac*;
- tensions arose as students and professionals shared the same building and equipment as a consequence of the observatory dual role as a teaching/research establishment;
- legislative changes disregarded the observatory specificity leading to several maladjustments and, namely, to a divergence of opinion regarding the nature of the relation, i. e. independence, of the observatory vis-à-vis the Faculty of Mathematics.

The Coimbra Astronomical Observatory was created as an establishment of the Faculty of Mathematics. According to the University statutes the Faculty of Mathematics professors accompanied by the Rector were required to inspect the observatory at the end of each academic year and any necessary improvements would be made forthwith at the University's expense [Universidade de Coimbra, 1772; p. 316]. According to the 1799 regulations the observatory director must be a retired professor of the Faculty of Mathematics. An 1836 law, forgetful of this particular requirement banned retired professors from attending the faculty congregations. As a consequence the observatory "became partly disconnected from the Faculty" [Universidade de Coimbra, 1871b]. Worse still, following his 1866 nomination as director Sousa Pinto claimed his presence was not required at the yearly faculty inspections. An interpretation that further eroded the authority of the faculty over the observatory. When Sousa Pinto failed to attend the 1867 visit, José Ernesto de Carvalho e Rego, the University Vice-Rector, asked the government to clarify the following points:

1. if the observatory director is or is not subject to the University Rector;
2. if the Faculty of Mathematics as a say in the observatory;
3. if the same faculty can or can not do the observatory visit as stated in the Universaty statutes.

Adding that an answer "is an urgent matter both for the rectorship as well as the faculty" [Rego, 1867]. Lacking a governmental reply the inspection visits were cancelled in 1868 and 1869. A new Rector, Júlio Máximo de Oliveira Pimentel, took office on 21 September 1869 and the inspection visits resumed the following year. Sousa Pinto was not present at the 23 June 1870 visit because of some unspecified personal reasons [Pimentel, 1871]. In the meantime the retirement regime of public servants changed on 17 June 1870. According to the new law no retired person could accumulate his pension with a salary. Unless an exception was made the observatory director, by statute, a pensioner would lose the complement to his pension [Universidade de Coimbra, 1871a; p. 44]. Replying to a different question the government ordered, on 21 June 1870, the rector to query, in writing, the Astronomical Observatory director and the Faculty of Mathematics about the

> organisation of the same observatory, staff qualifications and salaries, scientific research, and management taking into consideration the necessary economy for the treasury and the observatory astronomical work [Universidade de Coimbra, 1871a; p. 44].

In the discussions that followed a broad range of questions was raised and debated but we will focus on the organisation discussions since in our opinion this was what in the end conditioned the observatory research programme, in general, and of astrophysics, in particular [Bonifácio, 2009; Bonifácio, Malaquias, and Fernandes; 2006b].

Unable to agree upon a single document the appointed three member Faculty of Mathematics commission put forward two different proposals at the following congregation on 27 July. Luiz Albano and Jacome Sarmento re-claimed the observatory as a faculty establishment and proposed as its director the professor of the Practical Astronomy course. The proposal contemplated the creation of observer and calculator sections, the latter being responsible for the publication of the Coimbra Ephemeris. A set of astronomical observations was purposed and while the majority was astrometric spectral ones were also to be performed as soon as the appropriate instruments became available. As a transitory measure the current Director would be "the President and Director of the calculator section and will be in charge of everything relating to the calculation, printing and publication of Ephemeris". Although this corresponded to the de facto activity of the observatory director at the time, the measure thinly disguises what amounted to an attempt to shift the decision power from Souza Pinto to Luiz Albano. The third commission member, Florencio Barreto Feio (1819–1886), main suggestion was that the observatory direction should be shared by the director and the two astronomers/faculty professors. A proposal that could, in practice, imply a powerless director. By contrast Sousa Pinto's reply reinforced the current status quo. In his opinion the current legislation was sufficient [Universidade de Coimbra, 1871b].

The proposals were presented at the last congregation before the University summer break. Claiming lack of time to discuss them and the urgency of the matter the faculty decided to accompany its report with a copy of the proposals. The faculty was, in practice, 'washing their hands' from the process.

On 27 January 1871 the government send the process back to the Faculty of Mathematics requiring that a reform project was draw up. This would start a new round of meetings, discussions and proposals that culminated on April 17 when a reform plan was voted and Luiz Albano's position defeated. The final proposal established a Faculty - Observatory relationship defined by the following rules:

- "The exercises of the Practical Astronomy discipline can not disturb the Observatory work";
- "The Faculty of Mathematics inspection rights are limited to ensure that the Practical Astronomy discipline curriculum will be efficiently carried out."

That is the majority of professors supported the observatory independence on research matters as proposed by Sousa Pinto [Universidade de Coimbra, 1871a; p. 111].

The University Rector allegedly to provide a better idea of the faculty diversity of opinions sent to the government the defeated proposals, the "minutes of the sessions in which the final draft proposal of the astronomical observatory reform was discussed and approved and vote declarations". While he added "I have absolute confidence that the measures proposed by the majority of faculty will lead to the complete regeneration of the Astronomical Observatory of the University" one is left to wonder if a different governmental option was in reality desired [Pimentel, 1876; 5 May 1871]. Apparently the government too no action and while Sousa Pinto missed one more observatory visit, in 1871, from then on he apparently adopted the faculty recommendations.

Having at his disposal the instruments received from the 1870 solar eclipse expedition, the photoheliograph arrived in 1871 and the first Hoffmann direct vision spectroscope in March 1872, Luiz Albano started making astrophysical observations and experimenting with lunar and solar photography [Freire, 1872; p. 89, 90, 117]. He also included these topics on the Practical Astronomy course curricula. For example, in the academic year 1872-73 the students should describe a direct vision spectroscope and a photoheliograph, understand the physical constitution of the Sun, Moon and planets, observe solar and stellar spectra and compare them with spectra of known substances, and obtain direct and amplified photographs of the Sun and Moon [Universidade de Coimbra, 1873]. Small instruments, a Duboscq Silberman heliostat and a Steinheil table-top spectroscope, were bought and a new observing dome for the photoheliograph was finished in the observatory terrace around 1872 [Pinto, 1871; cartas de 2 de junho e 25 de outubro; Almeida, 1871].

Under Sousa Pinto leadership astrometry continued to be the observatory bread and butter. Not surprisingly in a May 1876 letter to Frederico Oom, Albano confides

> "For a long time I also tried to organise the practical work of the Observatory here, but I struggled in vain, making sacrifices and expenses, without success! [...] After a while I stopped fooling myself and entered the general rule of letting go" [Almeida, 1876].

In fact from 1876 onwards Luiz Albano became increasingly involved with secondary school policy matters and apparently lost interest in astronomy. Sousa Pinto, on the other hand remained the observatory director until his death in 1893 and excepting the 1900 solar eclipse observation we are not aware of any astrophysical research made at the Coimbra Observatory in the last quarter of the 19th century.

3.4 Solar Photography at the Infante D. Luiz Observatory

Brito Capello faced a completely different situation in Lisbon where he had the support of the Infante D. Luiz observatory director and the Polytechnic School council [Bonifácio, 2009; Bonifácio, Malaquias, and Fernandes, 2007; and references therein]. By the end of February permission had been granted to erect a small structure, paid by the government, on the grounds of the planned Polytechnic School Botanical Gardens. Brito Capello planned to use the Merz equatorial to study a possible relationship between the sunspots and the Earth magnetic field, especially, during strong magnetic disturbances. As a recording medium Capello opted for photography instead of drawing because it demanded less work and had greater accuracy although initially he was not sure he would be able to obtain the desired sunspot amplifications. Technically Capello followed Kew's approach and photographed the Sun's image after amplification by a secondary lens instead of using a long focus apparatus.

In the following months Capello sought advice from abroad namely from Kew Observatory, the leading solar observatory in the world, and Angelo Secchi at the Collegio Romano. Following the telescope installation a trial period began. The Moon and the Sun were photographed in August although poor telescope tracking constrained the lunar results. We have no record of further attempts to photograph the Moon at the observatory. Capello's early great solar photograph was probably taken on 13 October 1871. He described it as very sharp and sent it, at least, to father Angelo Secchi, Warren de la Rue (1815–1889) and the Paris and Kew Observatories. Throughout 1871 and 1872 Capello improved his method and increased the magnification of the sunspots photographed. The programme was well underway only limited by weather conditions and Capello's availability when the Portuguese were caught in the 1874 transit of Venus frenzy. Capello contemplated transporting the photoheliograph to Macao before September 1872. Likely the wet collodion response to the summer heat and optical apparatus distortions discussed with Angelo Secchi in July 1872 were already related to a possible transit expedition. Despite the favorable response from the Portuguese government the expedition budget of 11 contos was not approved by parliament. In a last attempt Capello unsuccessfully volunteered to join a British expedition [Capello, 1874]. During the preparations the solar photography programme was halted in September 1873 and the photoheliograph was dismantled while a camera was built with the recently acquired Dallmayer lenses [Capello, 1883].

After this debacle Capello resumed his daily solar photography at the Infante D. Luiz but in the following years the programme apparently fizzled out. In 1883 the surviving 407 negatives of acceptable quality were distributed according to table 1.

Year	1871	72	73	74	75	76	77	78	79	1880
Number		217	143		32					14

Table 1: Number of negatives of acceptable or better quality per year as defined by Capello in 1883.

This is clearly a subset since we known several photographs were taken in 1871 and that a large number of negatives were damaged due to the use of mercury, to enhance the images, a veneer of bad quality and their storage in a damp place where they were insufficiently protected from external agents. Despite this caveat we believe Capello's commitment to the solar photography decreased after 1875 due to several factors. The solar photography programme was essentially a one-man effort and on 30 April 1875 Capello was appointed the observatory director further increasing his workload and responsibilities. The solar cycle was near its minimum and sunspots and faculae appeared rarely. It became impossible to compete with the large scale photographs obtained, after 1876, by Jules Janssen (1824–1907) at Meudon [Solar Physics Committee, 1882; p. 239]. It must be realised Capello's main interest was not in keeping a daily photographic record of the solar surface but instead of taking sharper and more amplified images of sunspots. Without a better instrumental set-up this was impossible. Capello desire to test the large 38,2 cm aperture equatorial installed at Tapada da Ajuda in 1876 was apparently unfulfilled. In 1877 a new 11-inch Alvan Clark & Sons photographic equatorial was expected at the Lisbon Polytechnic School but unfortunately this turned out to be no more than wishful thinking (see section 4).

Despite the lacklustre programme closure on hindsight one realises that in 1870, only four observatories took daily solar photographs Kew and Ely in England, Vilnius in Lithuania and the Harvard College in the United States of America [Bonifácio, 2009]. All the other solar photographers were apparently not working on a regular basis. Capello's photographs were also amongst the best available anywhere. One was even chosen to illustrate Secchi's book *Le Soleil* [Secchi, 1877, p. 188].

4 The Lisbon Polytechnic Astronomical Observatory

In 1871 the Navy Astronomical observatory physical conditions were fast deteriorating and on 4 May the parliamentary treasury committee proposed its closure [Portugal. Câmara dos Deputados, 1871; p. 574]. At the time the Navy, Military and Lisbon Polytechnic school students had practical astronomy classes at the Navy Observatory. Concerned with the proposal impact the Navy Minister queried the schools about the matter. It became evident that the Tapada da Ajuda Observatory still under construction was not only ill equipped to be a teaching facility but its location in the outskirts of town was of difficult access for the students [Gouveia, 1871]. The legislature ended without a decision being reached on parliament but the issue kept surfacing until on 15 April 1874 the Navy observatory was closed down. Consequently Polytechnic, Naval and Military schools had to teach their own students [Portugal. Câmara dos Pares, 1874; Ministerio dos Negocios da Marinha e Ultramar, 1874]. A position previously supported by the Lisbon Polytechnic School council.

The Navy observatory instruments were distributed between the Tapada da Ajuda and D. Luiz observatories and the Naval, Military and Lisbon Polytechnic schools [Reis, 2009; p. 108].

This created an extra impetus to build the Polytechnic School Astronomical Observatory foreseen at time of the school foundation, 37 years earlier. The construction work started in 1874 and an observatory allocation appeared for the first time in the 1875-76 national budget. The role played by the school professors Marianno Cyrillo de Carvalho (1836–1905), member of parliament, and João de Andrade Corvo (1824–1900), Navy minister, in this process still needs further clarification [Bonifácio, 2009].

The observatory statutes were, apparently, never approved but from the proposals, discussions and public statements made one realises the school council desired a dual role - teaching and research - facility. Furthermore the two Lisbon astronomical observatories should complement each other. As the Tapada Observatory was build to be a first class astrometric facility the Polytechnic Observatory would focus instead on studying the celestial bodies by “astronomical spectroscopy and photography” [Corvo, 1877]. For this purpose an 11-inch photographic telescope was ordered from the american firm of Alvan Clark & Sons and governmental backing was requested to send an observatory astronomer to study abroad. On 18 June 1877, Henrique de Macedo Pereira Coutinho (1843–1910) was appointed to go on two study trips and learn “in Rome, Florence, Paris and Greenwich observatories the instruments and methods of astronomical spectroscopy and photography” [Coutinho, 1877]. The first trip lasted four months and was limited to the Rome and Florence observatories. Taking advantage of the end of the school year Henrique de Macedo left Lisbon on July 19. While in transit to Rome, where he arrived on August 7, Macedo visited Paris, Meudon and Milan observatories. In Rome, Macedo participated, under Respighi’s guidance, in some of the Capitol Observatory research programmes between August 12 and November 10. Due to Secchi’s absence for most of Macedo’s stay they first met on November 3. Macedo then had the opportunity to use the 19,5 inch Collegio Romano telescope before leaving to Florence on November 10. In Florence he made spectral planetary observations. On the 23 November Macedo started his return journey. Arriving in Lisbon 5 days later.

As the year 1877 come to an end there was an upbeat mood at the Polytechnic School judging by the speech given by its director on occasion of the annual student prize distribution on 21 December, according to whom the "observatory possesses instruments of exceptional quality". Celestial spectroscopy, astronomical photography and instructing the school students were the ends to which the observatory was essentially dedicated [Horta, 1878; p. 9]. As we will see reality differ quite substantially from this demagogic discourse.

At the end of 1877 the observatory building was completed and the library had more than one thousand volumes between modern and classical books. The observatory largest instruments were the Repsold meridian circle and a 6.5-inch equatorial received from the Navy observatory. The observatory also had four spectroscopes, one direct vision by Merz and three by Browing a tabletop, a six-prism automatic and a 2 prism stellar [Horta, 1878].

Upon his return to Lisbon, Henrique de Macedo helped by Marianno de Carvalho tested the observatory spectroscopes with the equatorial telescope. The six-prism automatic Browning and the Merz spectroscopes were used in observations of the solar limb and protuberances. Preferring the Merz model Macedo used it to determine the solar diameter. Spectra of Sirius and Mars were observed with the Browning stellar spectroscope [Coutinho, 1878].

On 1 August 1878 Henrique de Macedo left for his second trip abroad, intended to study astronomical photography. While abroad he tried unsuccessfully to extend its duration but had to return by December 1. We have no further details this second trip due to the lack of documental evidence. We know Macedo's expected report was not delivered by 16 June 1879 [Miranda, 1879]. Was it written?

The 11-inch photographic telescope order was being accompanied in the United States by Lewis M. Rutherfurd (1816–1892) that "rejected the first lens and only accepted the second after having made perfect photographs of the Sun, Pleiades that he sent to the school to be inspected". Although the telescope construction seemed on track on 22 April 1878 the instrument never arrived in Lisbon. It was later sold to Henry Draper (1837–1882) who used it to photograph for the first time a nebula, the Orion Nebula, on 30 September 1880 [Barker, 1888; p. 16]. After Draper's death the telescope 'distinguished career' continued at Harvard Astronomical Observatory where it was, for example, used to record thousands of stellar spectra [Warner and Ariail, 1996; p. 92].

Lacking this important asset the largest observatory equatorial was the 6-inch Repsold that had a lens of inferior quality, inhomogeneous and "barely usable to any dedicated observations, and worse still for spectroscopic ones" [Coutinho, 1878]. An assessment the Carl Zeiss Company confirmed in the early 20th century. On the other hand the observatory building was cramped, lacked stability and was in general poorly built. It was demolished and replaced by a new building before the end of the century [Silva, 1996].

There are no known astronomical works by either Henrique de Macedo or Marianno de Carvalho. Throughout the 19th century the Lisbon Polytechnic Astronomical Observatory failed to fulfilled the high ideals presiding at its construction it became in practice exclusively a teaching facility. In fact as far as it is known neither Henrique de Macedo nor Marianno de Carvalho published a single astronomical work.

5 Conclusions

In 1870 the three Portuguese astronomical observatories pursued astrometric research goals. Neither had made astrophysical observations nor had the equipment to do them.

The solar eclipse of 22 December 1870 brought to light the importance of astronomical photography and spectroscopy in solar studies. Although the eclipse observation was thwarted by the weather the expedition provided the opportunity to start-up astrophysical studies at several Portuguese scientific establishments as a consequence of the instruments bought and the know-how acquired in the process.

Following the expedition the government dispersed the instruments between the Lisbon Tapada da Ajuda and Infante D. Luiz Observatories and the Coimbra University Mathematical and Philosophy Faculties. The Tapada da Ajuda astronomers apparently lacked the drive to pursue astrophysical research and focused instead on the observatory chief aim, astrometric observations. The Coimbra Meteorological Observatory budget prevented Santos Viegas to join the observatory staff in the 1870's. The Merz equatorial telescope and spectroscope put at his disposal rested by all accounts unused under the observatory rotating dome.

In 1870 two different perspectives for the future development of the Coimbra University Astronomical Observatory were put forward. They had as their frontman the observatory director, Sousa Pinto, and the professor of Practical Astronomy, Luiz Albano, although the majority of Faculty of Mathematics professors, the Rector and even the government played an important role in the process. Sousa Pinto advocated better astrometric facilities while Luiz Albano wanted to start-up astronomical photography and spectroscopical studies. As we have seen it would be an oversimplification to interpret the process as a clash between the new generation and the 'old guard'. Other tensions perturbed, at the time, the regular operation of the observatory, in particular, an ill thought legislative framework. After spending months debating the observatory reorganisation the *status quo* was kept and Luiz Albano lacked the power to start up any research at the observatory without the approval of its Director. As the person in charge Sousa Pinto pursued the investment done in the publication of the observatory Ephemeris while waiting for the acquisition of new astrometric instruments.

Brito Capello implemented the most successful of all the research programmes generated by the 1870 solar eclipse expedition at the Lisbon D. Luiz Meteorological Observatory, taking advantage of the meteorological observatories network and, in particular, the good relationship with the Kew observatory staff. In his photographic programme Capello mainly sought to obtain the largest and sharpest images of sunspots possible. Capello corresponded and exchanged solar photographs with the world's best experts and his efforts were well received internationally, although he failed to analyse the results collected there was the expectation that they could hold the key to the comprehension of the observed correlation between the Earth's magnetic field variations and the solar activity cycle. In the early 1880's the photographic apparatus used by Capello had clearly been superseded by newer instruments available elsewhere which led to the programme demise.

Finally in 1874 the reorganisation of the astronomical teaching in Lisbon due to the closure of the Navy Observatory provided an extra impetus to build a new observatory at the Lisbon Polytechnic School focused on spectroscopical and photographic work. The failure to secure what would be the best photographic telescope in Europe an 11-inch Alvan Clark & Sons and the subsequent disinterest of the observatory astronomers transform it into merely a teaching facility.

In summary while historical research undoubtedly shows that the Portuguese practitioners 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 seldom successful task due to individual, institutional and material constraints coupled with a governmental lack of long-term planning.

References

Luiz Almeida, “Carta de 9 de junho”, Arquivo da Universidade de Coimbra (IV-2E-11-4-28), 1871.

Luiz Almeida, “Carta a Frederico Augusto Oom, 20 de maio”, Arquivo do Observatório Astronómico de Lisboa, 1876.

François Arago, “Sur l’éclipse totale de Soleil du 8 juillet 1842 “ in: *Annuaire pour l’an 1846 présenté au Roi par le Bureau des Longitudes*, Paris, Bachelier, 1845.

George Barker, *Memoir of Henry Draper (1837-1882)*, National Academy of Sciences, 1888.

Vitor Bonifácio, *Da Astronomia à Astrofísica: A perspectiva portuguesa*, Ph. D. thesis, Universidade de Aveiro, Departamento de Física, 2009.

Vitor Bonifácio, Isabel Malaquias, and João Fernandes, “The 1870 Portuguese solar eclipse expedition - a preliminary report” in: *Past Meets Present in Astronomy and Astrophysics*, 2006a, pp. 89–92.

Vitor Bonifácio, Isabel Malaquias, and João Fernandes, “Trying to start up the astrophysics research in Coimbra in the 1870’s. The difficult move from the classroom to the Observatory” in: Ana Breda, R. Duarte, and M. Martins (Eds.), *Proceedings of the International Conference in Mathematics, Sciences and Science Education. June 11-14, 2006, Aveiro, Portugal,* 2006b, pp. 7–15.

Vitor Bonifácio, Isabel Malaquias, and João Fernandes, “Solar Photography in the Nineteenth Century: the Case of the Infante D. Luiz Observatory in Lisbon (1871-1880)”, *Journal of Astronomical History and Heritage 10*(2), 2007, pp. 101–113.

Vitor Bonifácio, Isabel Malaquias, and João Fernandes, “Taking Internal Advantage of External Events -Two Astronomical Examples From Nineteenth Century Portugal”, *Centaurus 51* (2009*)*, pp. 213–234.

Alfred Brothers, “Photographs of the Solar eclipse of Dec. 21-22, 1870”, *Monthly Notices of the Royal Astronomical Society,* 31 (1871), pp. 167–171.

João Capello, “On an apparatus designed for the photographic record of the transit of Venus”, *Monthly Notices of the Royal Astronomical Society,* 34 (1874), pp. 354–356.

João Capello, “Lettre à le Solar Physics Committee, 7 Mars”, Biblioteca do Instituto Geofísico, Lisboa (Correspondência Estrangeira 1882-1883), 1883.

Joaquim de Carvalho, *Memoria historica da Faculdade de Philosophia*. Coimbra, Imprensa da Universidade, 1872.

João Corvo, “Carta de 25 de Maio”, Arquivo Nacional da Torre do Tombo, Secretaria de Estado do Ministério do Reino, Mç 3668, 1877.

Henrique Coutinho, “Carta de 29 de Dezembro”, Arquivo Nacional da Torre do Tombo, Secretaria de Estado do Ministério do Reino, Mç 3668, 1877.

Henrique Coutinho, “Relatório da 1ª viagem ao estrangeiro, 22 de Abril”, Arquivo Nacional da Torre do Tombo, Secretaria de Estado do Ministério do Reino, Mç 3668, 1878.

Warren de la Rue, “Address” in: *Report of the Forty-Second Meeting of the British Association for the Advancement of Science; held at Brighton 1872*, London, John Murray, 1873, pp. 312-317.

Filippe Folque, “Carta de 6 de Junho”, Arquivo Nacional Torre do Tombo, Ministério do Reino, Mç 3665, 1870.

Filippe Folque, “Relatorio da Commissão”, Arquivo Nacional da Torre do Tombo, Ministério do Reino. Maço 3655, Proc. 341, 1871.

Filippe Folque, *Relatorio dos trabalhos executados n’esta Direcção durante o ano de 1870 / Direcção Geral dos Trabalhos Geodésicos, Topograficos, Hidrográficos e Geológicos do Reino*. Lisboa, Imprensa Nacional, 1872.

Frederico Freire, *Memoria Historica da Faculdade de Mathematica*, Coimbra, Imprensa da Universidade, 1872.

Emília Gomes, *Desenvolvimento do ensino da Física Experimental em Portugal 1780-1870*, Ph. D. thesis, Universidade de Aveiro, Departamento de Física, 2007.

Emília Gomes and Isabel Malaquias, “The emergence of spectroscopy and its repercussions in the development of physics and chemistry teaching at the university of Coimbra in 19th century” in: *Proceedings of the 5th International Conference on the History of Chemistry -“Chemistry, Technology and Society”*, Aveiro, Sociedade Portuguesa de Química, 2006, pp. 579–590.

José Gouveia, “Continuação da discussão do parecer da commissão de fazenda acerca do orçamento do ministerio da marinha. Intervenção do sr. Ministro da Marinha”, *Diário da Câmara dos Deputados*, 1871, p. 618–621.

José Horta, *Relatório da Escola Politécnica 1877-1878*, 1878, pp. 41–46.

Gustav Kirchhoff, “On the simultaneous emission and absorption of rays of the same definitiva refrangibility”, *London, Edinburgh and Dublin philosophical magazine and journal of science,* 19, 4th series (1860), pp. 195–196.

Samuel Langley, “The American Eclipse Expedition”, *Nature*, 3 (1871), pp. 228–229.

Lopes, A., Observatorio Meteorologico e Magnetico da Universidade de Coimbra, Coimbra, Imprensa da Universidade, 1892.
Ministério do Reino, "Portaria do Ministerio do Reino de 4 de Janeiro", Arquivo da Universidade, Coimbra, Correspondência do Ministerio do Reino 1843 -1910 cx 35, 1871.
Ministerio dos Negocios da Marinha e Ultramar (1874). Carta de lei de 15 de abril. *Diário do Governo*.
F. Miranda, "Cópia da carta ao Conselho da Escola Politécnica, 16 de Julho", Arquivo Nacional da Torre do Tombo, Ministério do Reino, Mç 3668, 1879.
Alex Pang, *Empire and the Sun*, Stanford University Press, 2002.
Alfredo Peixoto, *Movimento do centro de gravidade do systema planetário*, Coimbra, Imprensa da Universidade, 1870.
Júlio Máximo de Oliveira Pimentel, "Carta de 15 de janeiro", Arquivo Nacional da Torre do Tombo, Ministério do Reino, Mç 3654, 1870.
Júlio Máximo de Oliveira Pimentel, "Carta de 26 de julho", Arquivo Nacional da Torre do Tombo, Ministério do Reino, Mç 3657, 1871.
Júlio Máximo de Oliveira Pimentel, Arquivo da Universidade de Coimbra, Reitoria Oficios Expedidos 1870-1876, lv 2 (IV-2E-11-1-5), 1876.
Júlio Máximo de Oliveira Pimentel, *Exposição succinta da organização actual da Universidade de Coimbra*, Coimbra, Imprensa da Universidade, 1878.
Rodrigo Ribeiro de Sousa Pinto, *Adittamento ao calculo dos eclipses*, Imprensa da Universidade de Coimbra, 1868.
Rodrigo Ribeiro de Sousa Pinto, Arquivo da Universidade de Coimbra (IV-2E-11-4-28), 1871.
Portugal. Câmara dos Deputados, "Parecer da commissão de fazenda ácerca do orçamento do ministerio da marinha", *Diário da Câmara dos Deputados*, (1871), pp. 569–583.
Portugal. Câmara dos Pares, "Sessão de 6 de Fevereiro", *Diário da Câmara dos Pares*, (1874), pp. 27-30.
Pedro Raposo, *A vida e obra do Almirante Campos Rodrigues*, Master's thesis, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, 2006.
José Real, Manuel Rocha and Augusto Castro, *Viagem dos imperadores do Brasil em Portugal*. Coimbra, Imprensa da Universidade, 1872.
José Rego, "Carta de 27 de julho", Arquivo Nacional da Torre do Tombo, Ministério do Reino, Mç 3657, 1867.
António Reis, *Observatório Real da Marinha*, Lisboa, CTT Correios de Portugal, 2009.
Giovanni Santini, *Rapporti sulle osservazioni dell'eclisse totale di sole del 22 dicembre 1870 eseguite in Sicilia dalla commissione italiana*, Palermo, Stabilimento tipografico Lao, 1872.
Angelo Secchi, *Le Soleil,* vol. 2, Paris, Gauthier-Villars, 1877.
Secretaria Geral do Ministério do Reino. Registo de correspondência e providências sobre comissões ou viagens científicas, Arquivo Nacional da Torre do Tombo, Ministério do Reino, Lv. 1038.
Vasco Silva, *Do Antigo Observatório Astronómico da Escola Politécnica e da sua Musealisação*, Master's thesis, Departamento de Antropologia da Faculdade de Ciências Sociais e Humanas da Universidade Nova de Lisboa, 1996.
Solar Physics Committee, *Report* , London, Eyre and Spottiswoode, 1882.
Jacintho Souza, *Relatorio da Visita aos Estabelecimentos Scientificos de Madrid, París, Bruxellas, Londres, Greenwich e Kew*, Coimbra, Imprensa da Universidade, 1862.
Jacintho Souza, "Observatorio Meteorologico e Magnetico", in: *Memoria historica da Faculdade de Philosophia*, Coimbra, Imprensa da Universidade, 1872, pp. 193–198.
Universidade de Coimbra, *Ephemerides Astronomicas para o anno de 1870*, Coimbra, Imprensa da Universidade, 1868.
Universidade de Coimbra, Actas da congregação da faculdade de mathematica, vol. 4 (1866-1871), Arquivo da Universidade de Coimbra (IV-1a-D3-1-79), 1871a.
Universidade de Coimbra, Reforma do observatório astronómico, 1871b.
Universidade de Coimbra, *Programas dos Estudos de Cada uma das Cadeiras das Diferentes Faculdades da Universidade de Coimbra no Anno Lectivo de 1872-1873*, Coimbra, Imprensa da Universidade, 1873.
Universidade de Coimbra, *Estatutos da Universidade de Coimbra*, Coimbra, Imprensa da Universidade, 1972.
Deborah Warner and Robert Ariail, *Alvan Clark & Sons, Artists in Optics*, Richmond, Willmann-Bell, Inc., 1996.
Johann Zöllner, *Photometrische untersuchungen mit besonderer rücksicht auf die physische beschaffenheit der himmelskörper*, Leipzig, Verlag von Wilhelm Engelmann, 1865.