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## **Reacting to external events: Solar eclipses as catalysts of the Portuguese astronomical development in the second half of the nineteenth century**

### **(1) Introduction**

The 19<sup>th</sup> century saw dramatic changes in that oldest scientific discipline — astronomy. The appearance of the photographic and spectroscopic techniques revolutionized the daily routine of astronomical observatories. The amount of information extracted with these new means made astronomical research what it is today. The adherence to these powerful techniques was nevertheless not instantaneous. It took decades for the first research institutions dedicated to the new field of astrophysics to be implemented. Their adoption depended on a range of factors namely the particular structure supporting the astronomical research and the philosophy behind it (a point made clear in the different British and continental Europe approaches<sup>1</sup>), the available funds and last but not the least the will of the protagonists themselves, especially if their number was small. In Portugal the implementation of these techniques was slow and from what we can gather today was led by a particular type of celestial phenomena — solar eclipses — that we decided to call “external events”, in the sense that their occurrence is uncontrolled by local protagonists.

The 19<sup>th</sup> century increased interest in solar eclipses is a natural offshoot of a grown interest in the solar studies as consequence of the new technical means available as well as the new research results, namely, the establishment of a solar activity — earth magnetism connection in the 1850’s. Large expeditions were sent to exotic and faraway locations in an attempt to observe the fleeting moments of totality in which information about the protuberances and corona could be obtained. Simultaneously attempts were made to develop techniques freeing the scientists from this constraint. Some were quickly successful like the spectral observation of protuberances developed simultaneously in 1868 by Jules Janssen and Norman Lockyer while Bernard Lyot’s coronagraph only appeared in the 20<sup>th</sup> century.

In this article we will analyse the Portuguese observations of the solar eclipses of 1858 March 15, 1860 July 18 and 1870 December 22 and their consequences.<sup>2</sup> Following this later eclipse the study of astrophysics developed in several Portuguese institutions albeit with different success.

### **(2) Portuguese solar eclipse observations: 1858–1860**

The annular eclipse of 1858 March 15 was special in the sense that the maximum duration had, according to recent calculations,<sup>3</sup> the small value of 2s. Contemporaneously this led to a kind of public relations problem since due to the uncertainties in the sun and moon apparent motions and dimensions the astronomers were uncertain about the type of eclipse that would occur. Would it be a total or an annular eclipse? That would be an observable difference, even to the less elevated member of the public. One thing was certain the eclipse would be partial in Portugal and it was observed in the only two astronomic observatories of the country, the Coimbra University Observatory and the Navy

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<sup>1</sup> A. J. Meadows. *Science and controversy — a biography of Sir Norman Lockyer* (Macmillan, 1972).

<sup>2</sup> The solar eclipse of 1900 May 28 will not be considered since any impact was already felt in the 20<sup>th</sup> century.

<sup>3</sup> Eclipse Predictions by Fred Espenak, NASA/GSFC, <http://sunearth.gsfc.nasa.gov/eclipse/SEcat/SE1801-1900.html>.

Observatory, located in Lisbon.<sup>4</sup> The observations, done with small telescopes, were in both locations successful and consisted in measuring the times of contact with the objective of correcting differences of longitude between locations and/or improving the astronomical tables. It was known that the observations were not precise enough, uncertainties of several seconds were typical in the timing of the first and fourth eclipse contacts, and that the improvement of the astronomical tables was difficult due to high number of free parameters. George Airy considered, in 1833, for instance, the beginning or the end of a solar eclipse so unsatisfactory that he did not think it worthwhile to note them at all.<sup>5</sup> In 1858, the determination of longitude was clearly outdated in face of the ease of use and precision obtained with the telegraphic method.

Different observations were attempted elsewhere particularly by Emmanuel Liais in Cherbourg<sup>6</sup> and Porro in Paris. Liais intended to obtain photographic, spectroscopic and photometric data even in the absence of a theoretical interpretative framework, as was the case for spectroscopy. In Paris, solar photographs of the eclipsed sun were obtained and micrometric measurements performed in view of correcting the astronomical tables.<sup>7</sup> Hervé Faye already proposed this eclipse as a testing ground for

... d'autres occasions plus importantes encore, telles que le belle éclipse totale que nous irons observer dans deux ans en Espagne, à Alger, sur les bords de la mer Rouge et sur ceux de l'océan Pacifique.<sup>8</sup>

Not surprisingly high hopes were reserved for the 1860 July 18 solar eclipse whose path of totality crossed Spain and a large number of observers came from all over Europe to observe the event.<sup>9</sup> The Portuguese astronomers were not insensitive to this opportunity and a four men expedition was put together with government support. The expedition members were Rodrigo Sousa Pinto, the first astronomer of the Coimbra Observatory and professor of Mathematics, at the University of Coimbra, Jacinto de Sousa, professor of Philosophy at the University, João de Brito Capello, the main observer of the Infante D. Luiz Meteorological Observatory in Lisbon, and Mr. Miranda, a technician. The expedition was hastily put together and

... had to leave immediately to the observing station with the instruments available in Coimbra and Lisbon none of them purposely built for the eclipse observation.<sup>10</sup>

Consequently, since neither one of the new photographic and spectroscopic techniques were used by Portuguese astronomical community, all observations were visual in nature and the expedition objectives were similar to those of the 1858 eclipse, that is, to calculate differences of longitudes and correct astronomical tables complemented by meteorological observations.

Internationally a large effort was put into photographing the phase of totality. José Monserrat with the father Secchi's Cauchoix equatorial and Warren de La Rue with his photoheliograph obtained successful photographs by which the unequivocally solar origin of the observed protuberances was deduced.<sup>11</sup>

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<sup>4</sup> L. Albano, "Eclipses do sol", *O Instituto, Jornal Científico e Litterario*, 1 (1858), p. 5–6; R.R.S. Pinto, "Eclipse do sol em 15 de março de 1858", *O Instituto, Jornal Científico e Litterario*, 7 (1858), p. 22–23.

<sup>5</sup> G.B. Airy, "Observations at Cambridge", *Monthly Notices of the Royal Astronomical Society*, 3 (June 1834), p.53.

<sup>6</sup> M. E. Liais, "Observations faites à Cherbourg sur l'éclipse du 15 mars 1858", *CRAS*, 46 (1858), p. 654–658.

<sup>7</sup> M. Faye, "Observations photographiques de l'éclipse, faites avec la grande lunette de M. Porro", *CRAS*, 46 (1858), p. 507.

<sup>8</sup> M. Faye, "Indications soumises aux photographes, relativement à l'éclipse du 15 mars", *CRAS*, 46 (1858), p. 479–482; "... even other more important occasions, such as the beautiful total eclipse we will observe in two years in Spain, in Alger, near the margins of Red Sea and in those of Pacific Ocean."

<sup>9</sup> Expeditions from Bavaria, Denmark, France, German States, Great Britain, Italia, Portugal, Prussia, Russia and Switzerland went in Spain to observe the eclipse — *Anuario del Real Observatorio de Madrid — Ano II – 1861* (Madrid: Imprenta Nacional, 1860).

<sup>10</sup> R.R.S. Pinto, *Eclipse solar de 18 de julho de 1860. Memoria apresentada ao excellentissimo ministro do reino pela comissão portugueza* (Imprensa da Universidade de Coimbra, 1860).

<sup>11</sup> M.L. Arroyo, *El Real Observatorio Astronómico de Madrid (1785–1975)* (Dirección General del Instituto Geográfico Nacional, 2004).

Several other important eclipse observations and expeditions occurred during the 1860's namely the 1868 and 1869, in which the first spectroscopic observations of the protuberances and corona were performed, respectively.

### (3) Portuguese Astronomy in the 1860's

During the 1860's the Coimbra and the Navy observatories did not acquire significant new equipment neither changed their scientific astrometric research goals.<sup>12</sup> In Coimbra, the calculation of the *Ephemerides* was that said significantly improved. The new Lisbon Royal Astronomic Observatory modeled after the Pulkova Observatory was being constructed in Tapada da Ajuda from 1861 but its main research plan was again astrometric in nature.

Nevertheless the recent astronomical developments were known by the Portuguese scientists either by way of international publications or by a first hand contact with colleagues working abroad via scientific travels. For instance in a letter dated from 1870 March 21, Sousa Pinto at the time director of the Coimbra Observatory writes to the Principal of Coimbra University

The best star catalogues and the most important astronomical publications from Germany, England, France and the United States exist today in the Observatory Library.

Also immediately after the 1860 eclipse, the three Portuguese eclipse observers were instructed by the government to visit important scientific institutions in Spain, France, Belgium and Great Britain. Jacinto de Sousa returned again to Great Britain in 1861 and Brito Capello, in 1863 and 1865, mainly due to the installation of the magnetic observatories in Portugal<sup>13</sup> of which Kew was a model, and where the photographic study of the solar activity was pursued, under the auspices of the British Association for the Advancement of Science. Frederico Augusto Oom stayed in Pulkova between 1858 and 1863 learning the necessary astronomical skills to be used in the new Lisbon Observatory. At last António dos Santos Viegas performed a prolonged trip abroad from 1866 December to 1867 November. All these scientists would be involved in the 1870 Portuguese solar eclipse expedition. Notwithstanding there was no attempt to use photography or spectroscopy in a Portuguese Astronomic Observatory before the 1870 eclipse effort.

### (4) The total solar eclipse of 1870 December 22

The eclipse of December 22 was predicted in the *Coimbra Ephemerides* for the year 1870, published in 1868 and the path of totality would cross the southern part of Portugal, namely the Algarve. Local circumstances for several Portuguese towns were also calculated in the *Ephemerides*.

This was an opportunity not to be missed and the Faculty of Mathematics was on the move as early as 1869 October 27. A commission was nominated by the Faculty Congregation to provide an expedition proposal to be presented to the government.<sup>14</sup>

One of the first actions taken by this commission was to write to several foreign scientists asking for advice in the expedition planning. In a letter to father Angelo Secchi, one of the most important solar experts of the day, we can read:

The Coimbra Faculty of Mathematical Sciences proposes to observe this phenomenon; and wishing to make it in a useful manner for science, it believes that it must find the benevolent co-operation of foreign savants, who have been most occupied with the questions of physical astronomy.<sup>15</sup>

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<sup>12</sup> The Lisbon Navy Observatory was extinct by the government in 1874.

<sup>13</sup> Isabel Malaquias, Emilia Vaz Gomes, D. R. Martins: "The genesis of geomagnetic observatories in Portugal", *Earth Sciences History* 24(1) (2005), p. 113–126.

<sup>14</sup> An article is being prepared on the details of this expedition in the meantime for a brief account see V. Bonifácio, I. Malaquias, and J. Fernandes, "The 1870 Portuguese solar eclipse expedition — a preliminary report", in: A. M. José Afonso, Nuno Santos and R. Agostinho, (eds.) (2005): *Past meets present in Astronomy and Astrophysics, Proceedings of the 15th Portuguese National Meeting* (World Scientific, 2006).

<sup>15</sup> "La faculté des Sciences Mathématiques de Coimbra se propose d'observer ce phénomène; et désirant le faire d'une manière utile pour la science, elle croit devoir se procurer la coopération bienveillante des savants étrangers, que se sont le plus occupés des questions de physique astronomique."

This introduction is followed by a series of very specific questions:

- What are the most important physical observations one can make during an eclipse?
- If spectral observations are to be performed what instrument would be advisable to use? And which spectroscopy instrument-maker would father Secchi recommend?
- Would a photoheliograph be indispensable?
- To observe the eclipse phases which is the most advantageous: a reflection or a refraction telescope?

Secchi's reply is lost but the expedition scientific objectives show a clear shift in paradigm when compared with the previous efforts as can be ascertain by the 1870 January 15 proposal to the government:

Today the physical part of the luminous phenomena from which observation and analysis depends, the solution of the unanswered questions about the sun's physical constitution, is the one to which more attention should be spent.

and specific objectives were:

- Determination of the stations co-ordinates and clocks rates;
- Observation of phases, diameters and sunspots;
- Spectral, photometrical and polarimetrical observations;
- Photographs and drawings of the corona, protuberances and phases.

The proposal clearly specifies that only the instruments strictly necessary should be acquired but on the other hand the instruments used must be of such a high standard that the observations could have scientific interest. The government agreed with the recommendation and in an 1870 February 8 law required the co-operation of all the Portuguese scientific establishments in providing instruments to the eclipse expedition. The unavailable instruments would be bought.

As time progressed a larger participation of the Portuguese scientific community in the eclipse expedition effort is observed. In the end all national observatories both astronomical (Coimbra, Navy, Lisbon Tapada) and meteorological (Coimbra, Infante D. Luiz) as well as the Coimbra University and the Lisbon Industrial Institute were somewhat involved.

Contacts with foreign scientists pursued during the expedition preparation. For instance, Capello asked Balfour Stewart for an eclipse map done by Mr. Hind of the *Nautical Almanac*<sup>16</sup> to be sent to Lisbon. We also know that the results obtained by the US Naval Observatory party in the 1869 August eclipse were sent to Lisbon by July 1870. One of the most important decisions taken was to send Professor Santos Viegas to Rome to study the solar application of spectral analysis with father Secchi in the summer of 1870. While in Rome, Santos Viegas contacted both with father Secchi and Lorenzo Respighi, two of the leading specialists in the area and used their spectroscopes.

There was also the idea of inviting international expeditions that would like to come to Portugal to observe the event. We did not find any indication that a Portuguese location was internationally considered, even with the *Nautical Almanac* containing the local circumstances for Tavira in Algarve. Nevertheless, special Portuguese maps in which the eclipse path of totality was marked were sent abroad. And we also found, in the previously letter from Capello to Balfour Stewart, a precise description of the Portuguese chosen station in Tavira,

We have chosen a farm near Tavira and very near the central line. There is in the neighbourhood of this village very appropriate means for the observation very near the telegraphic line, and the roads are good enough for the transportation of instruments and observers. I think that our stations in south Portugal should be preferred by the British and German astronomers to those of Spain and Sicily as the totality time is bigger in Portugal and the climate is more or less the same; although the period of the year is very bad for all the stations.<sup>17</sup>

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<sup>16</sup> Letter to Balfour Stewart, 1870 April 22.

<sup>17</sup> "Nous avons choisi une ferme tout près de Tavira et très proche de la ligne central. Il y a dans les alentours de cette ville des lieux très appropriés pour l'observation très prochains de la ligne telegraphique, et les chemins sont généralement assez beaux pour le transport des instruments et observateurs."

Unfortunately Capello was not wrong in his weather assessment and on the 22<sup>nd</sup> the rain thwarted the entire Portuguese endeavour as well as several other expeditions located elsewhere.

Nevertheless the insight of the Portuguese scientists and government in their observational effort may be judged by the high number of foreign expeditions and effort put in the eclipse observation even taking into account the favourable path of totality that crossed several European countries and by the persons involved in observations amongst them Huggins, Janssen, Lockyer, Newcomb, Secchi, Tacchini, Vogel and Young.

As we have already mentioned the weather did not help the observations but several important results were secured. Confirmation of the 1869 green emission coronal line was obtained. Photography assigned a solar origin to, at least, the inner observable corona. And Young in Spain observed for the first time the expected inversion of the solar spectrum.

The eclipse also stimulated the development of solar studies namely leading to the creation of the Società degli Spectroscipisti Italiani as part of an effort to monitor the solar activity and the publication of the *Memorie della Società degli Spectroscipisti Italiani*, the first astrophysical journal in the world. A few years later the first astrophysical observatories of Potsdam, Meudon and South Kensington were created.

## (5) Conclusion

The Portuguese government decided on 1871 January 4 that the eclipse participating institutions should divide among them the equipment bought for the expedition: three equatorial telescopes clockwork driven by Merz, a photoheliograph by Steinhell and two direct vision spectroscopes also by Merz.<sup>18</sup>

We are currently in the process of tracking this equipment and researching its influence in the Portuguese astrophysical studies but we have already found out that the photoheliograph was given to the Faculty of Mathematics of the Coimbra University to be used by the professor of Practical Astronomy. As a consequence a curriculum containing solar photography and spectroscopy was implemented in the discipline. A more ambitious research project by professor Luiz Albano, the Observatory second astronomer, met with resistance by the Observatory director and part of the Faculty of Mathematics due to the particular predicament of the institution and the country financial difficulties, and was abandoned.<sup>19</sup>

One of the Merz equatorials was given to the Infante D. Luiz Meteorological Observatory in Lisbon where under the supervision of João de Brito Capello a successful program of solar photography was implemented during the 1870's.<sup>20</sup>

After this interval in the 1870's the Portuguese astronomical main research interests focused again in the classical astrometric work although during the 19th century at least another serious attempt was made to implement the more „modern” astrophysical studies at the Lisbon Polytechnic Observatory when it was created in 1875. Only in the first quarter of the 20th century astrophysical observations were again implemented at the Coimbra Observatory in a solar monitoring program that continues till today.

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Je crois que les nôtres stations du sud de Portugal doivent être préférées à celles d'Espagne et Sicile pour les astronomes anglais et Allemands vu que le temps de totalité est plus grand à Portugal et le climat est à peu près le même; l'époque est qui est très mauvaise pour toutes les stations.”

<sup>18</sup> F. C. Freire, *Memoria Historica da Faculdade de Mathematica nos cem annos decorridos desde a reforma da Universidade em 1772 até o presente* (Imprensa da Universidade de Coimbra, 1872).

<sup>19</sup> V. Bonifácio, I. Malaquias, and J. Fernandes, “Trying to start up the astrophysics research in Coimbra in the 1870's. The difficult move from the classroom to the Observatory”, in: M. Martins, A. Breda, R. Duarte, (eds.), *Proceedings of the International Conference in Mathematics, Sciences and Science Education* (Universidade de Aveiro, 2006).

<sup>20</sup> V. Bonifácio, I. Malaquias, and J. 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*, vol. 10 (2007), p. 101–113.