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THEMATIC DOSSIER
TOWARDS A GLOBAL HISTORY OF ECLIPSES.
ENTANGLEMENTS OF DISCIPLINES, ACTORS, AND PRACTICES

Towards a Global History of the 1860 Total Solar Eclipse

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Abstract: The path of eclipse totality across North America, Spain, and Northern Africa on 18 July 1860 was accessible to a wide range of observers in diverse geographical and socio-political contexts, the infrastructures of which shaped individual expedition logistics. This joint paper combines in a single frame of reference accounts from British, French, Spanish, Portuguese, Italian, Algerian, and North American expedition parties. A focus on the scientific objectives of these observers with varied circumstances, institutions, and funding sources raises the question of a global approach to the history of observing the total solar eclipse in 1860.

Keywords: 1860 total solar eclipse; global history; astrophotography; astronomical expeditions; international collaboration

Introduction

On 18 July, 1860, a path of solar eclipse totality crossed North America, Spain, and Northern Africa. This fourth total solar eclipse across Europe within twenty years arrived at a time of considerable technological development that generated enthusiasm for astronomical observations and ushered in the golden age of eclipse expeditions. Although astronomers in South America had tried to excite broad interest to observe total solar eclipses in Brazil in 1858 and South America in 1855, neither of these events had the global engagement or evident impact of 1860. The 1860 event marks the first widespread and highly anticipated global effort to observe a total solar eclipse.[1] Astronomers in Spain, Egypt, Algeria, and North America could view the solar corona with only domestic travel. For hopeful observers based in the UK, France, Germany, Austria, Sweden, Switzerland, Russia, Prussia, Italy, and Portugal, travel to the zone of totality in Spain was comparatively straightforward, eased by both proximity and railroads to transport bulky and breakable equipment.

Figure 1. The path of the total solar eclipse of 18 July 1860 with observing locations marked.

The concentration of varied geo-political entities in the path of totality in 1860 provides a rich context that highlights the degree to which different political contexts and institutional structures shape an eclipse expedition. Astronomical expeditions can be high-risk projects involving significant human and monetary resources marshalled for observations that can

[1] Arthur Cowper Ranyard, "Index of MS and Printed Accounts of Observations," *MRAS* Vol XLI. (1879): 732-733.

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be thwarted by a single cloud. The practicalities of such expeditions are comparable to small-scale military operations with demands for logistical sophistication, extensive manual labour (much of which is performed by hidden actors), and diplomatic negotiation. The Spanish government, in particular, made overtures to foreign expeditions in 1860 and envisioned a prominent role for the Madrid Observatory in coordinating observation efforts.

Activity at the Madrid Observatory had nearly ground to a halt in the early nineteenth century due to occupation by Napoleonic troops during the Spanish war of Independence (1808-1814). The large Herschelian telescope was dismantled for ammunition parts and the building transformed into a powder magazine. Between 1847 and 1851, Antonio Gil de Zárate, Royal Commissioner for the Observatory, sparked a mid-century revitalisation by sending mathematicians Aguilar and Novella to major European observatories for astronomical training, to view their instruments and connect with the best contemporary astronomers. In 1851, Aguilar was appointed director and Novella first astronomer at the Madrid Observatory. The equipment was renovated and in 1859 the first volume of the observatory annual report (Anuario) appeared. While astronomers had been involved in geodetic work for the map of Spain, the first strictly astronomical challenge for the revived Madrid Observatory was the organisation of observations for the 1860 total solar eclipse.[2]

Gil de Zárate was by then undersecretary of Spain's Ministry of the Interior, having been appointed in 1856 during a rare period of political stability following Queen Isabel II's approval of the constitution and formation of a broad-based government by the Unión Liberal (gobierno largo, 1858-1863). The eclipse of 1860 gave the Spanish government an opportunity to show the rest of Europe that the absolutism was over: Spain was now a modern nation. They aimed to involve academies, universities, colleges, amateur astronomers, and all cultural components of Spanish society in the observation of the eclipse. Most importantly, the Spanish government decreed that all foreign expeditions would benefit from free customs charges, assistance from local authorities, and staff from local universities. In May 1860, Madrid Observatory director Aguilar wrote to all the heads of the foreign expeditions, asking them to communicate details—ports of landing, and the number of crates with content lists, and the need for telegraphic connections. Although this communication arrived too late for many expeditions, the Spanish government's gesture nonetheless demonstrates a collegial and collaborative welcome to foreign observers.

While the many expeditions in Spain and elsewhere were not all explicitly connected, they nonetheless evidence similar approaches and share a consistency across research goals.

[2] Antonio E. Ten, Joaquín Castro Soler and J. María López Piñero, "José Monserrat y Riutort y el Primer Descubrimiento de la Fotografía Astronómica: Las Fotografías del Eclipse de Sol de 1860," *Archives Internationales d'Histoire des Sciences* 47 (1977): 3-26.

The nature of the solar prominences was one open question with three theories: were the prominences a property of the Sun (topographic); due to the terrestrial atmosphere (atmospheric); or due to optical effects of diffraction, interference, and radiation (optical)?[3] Photography was considered the best means to investigate the solar prominences and validate one of these theories. Mid-century advances in photographic techniques—including locating the ultraviolet focus of telescopes—brought the first photograph of the solar corona in 1851.[4] Stunning lunar images in the 1850s and 1858 photographs of Donati's comet further excited interest in astrophotography and its scientific potential for examining the red solar prominences.[5]

Beyond observing coronal phenomena during the 1860 total solar eclipse, astronomers also hoped to time the phases, to test telescope clocks, and to use contact times to check the precision of their lunar tables. Some observers, particularly from France and North America, aspired to discover an intra-Mercurial planet. Additional aims included detecting possible meteorological and geomagnetic variations during the eclipse and taking polarimetric and solar radiation measurements. Each open question involved a scientific framework that required technical competencies, mobilisation of both people and equipment, and, crucially, adequate financial resources. Following the total solar eclipse on 18 July, 1860, expeditions to observe eclipse totality became a regular feature in the astronomical calendar as opportunities to pursue research questions.

This paper features individual case studies of expeditions from Britain, France, Spain, Portugal, Italy, Algeria, and North America that focus on scientific objectives within varied circumstances, institutions, and funding sources. Certainly, others from Central and Northern Europe also organised to observe eclipse totality in Spain. One such large expedition included Johann Heinrich Mädler from Dorpat (today Tartu) Observatory and his wife Minna Mädler (née Witte), as well as astronomers Heinrich Louis d'Arrest and Thorvald Thiele from Copenhagen and others who observed from northern Spain, at Vitoria.[6] Mädler published a complete report of all observations made in Spain, which is a valuable reference for the 1860 eclipse.[7] While the contexts explored below are thus far from

[3] Manuel Camseco Caballé, *Eclipses Totales de Sol en Castelló de la Plana 1860 y 1905* (Castelló de la Plana: Ayuntamento de Castellón de la Plana & Planetario de Castellón, 2005), 89.

[4] Reinhard E Schielicke and Axel D. Wittman, "On the Berkowski Daguerreotype (Königsberg, 1851 July 28): The First Correctly-exposed Photograph of the Solar Corona," in *Development of Solar Research. Acta Historica Astronomiae* 25, eds. Axel D Wittman, Gudrun Wolfschmidt, Hilmar W Duerbeck, 128-147 (Frankfurt am Main: Verlag Harri Deutsch, 2005).

[5] Jay M. Pasachoff, Roberta J.M. Olson and Martha L. Hazen, "The Earliest Comet Photographs: Usherwood, Bond, and Donati 1858," *Journal for the History of Astronomy*, xxvii (1996): 129-145.

[6] See Arthur Cowper Ranyard, ed., "Observations Made During Total Solar Eclipses", *Memoirs of the Royal Astronomical Society* XLI (1879), 767.

[7] Johann Heinrich Mädler, *Über Totale Sonnenfinsternisse mit Besonderer Berücksichtigung der Finsterniss vom*

comprehensive, this preliminary investigation nonetheless raises questions and explores the potential of formulating a multi-author global approach to the history of observing the total solar eclipse in 1860.

Spanish Expeditions and Joint Collaborations

Spain was not only host and administrative hub for visiting expeditions, but its two main observatories – the San Fernando Spanish Naval Observatory in Cadiz and the Madrid Observatory –also prepared expeditions. The San Fernando party involved members of the Spanish military, who were joined by academics and naval officers from Portugal. The Madrid party included a range of Spanish academics and a Jesuit priest; they were joined by a small French expedition with an Egyptian astronomer. They observed the phenomenon from three different places, to reduce risk of failure due to weather: some observed from Moncayo, near Zaragoza, while others decided to move to nearby heights in Tarazona. A third party went to Desierto de las Palmas, near Castellón de la Plana.[8]

The Spanish-Portuguese Expedition to Oropesa

The San Fernando expedition was headed to Oropesa del Mar, located on the Mediterranean coast in the zone of totality, not far from Castellón de la Plana. The party included: Francisco de Paula Márquez, director of the Observatory; Enrique Garrido, astronomer at San Fernando; Manuel Fernández Coria and Agustín Serrano Mayoral, lieutenants of the Spanish Royal Navy; José Montojo and Jacobo José Gordón, lieutenants of the Naval Engineering Corps; Cecilio Pujazón and Simón Manzanos, second lieutenants of the Spanish Royal Navy.

A Portuguese expedition with scientists from Coimbra and Lisbon observatories also joined the San Fernando expedition. The group was led by Rodrigo Ribeiro de Sousa Pinto, director of the Coimbra Observatory, and included Francisco António de Miranda, a mechanic from the same observatory, as well as Jacintho António de Sousa, Professor of Physics of the Coimbra Faculty of Philosophy, and João Carlos de Brito Capello, Navy Officer and meteorologist at the Meteorological Observatory of Infante Dom Luís in Lisbon. Initially, they planned to observe in Moncayo, then realised that travel would be difficult, so moved to Castellón de la Plana, where they met the San Fernando expedition.

18. Juli 1860 (Jena: Friedrich Fromman, 1861).

[8] Francisco de Paula Marquez, *Memoria Sobre el Eclipse de Sol de 18 de Julio de 1860* (Madrid: Imprenta de Fortanet, 1861), 2.

Together, they went to Oropesa with a programme that called for: Sousa Pinto and Miranda to focus on astronomical observations using Dollond equatorial achromatic telescopes from Coimbra Observatory; Sousa and Brito to make magnetic and photometric observations (and, if possible, to observe the corona and prominences) using a telescope from the meteorological observatory of the Escola Politécnica in Lisbon; Montojo and Gordòn to make meteorological observations using thermometers, a barometer, and a hygrometer; Serrano and Pujazòn to do actinometric observations using a thermomultiplier; Garrido and Manzanos to do observations of solar corona and prominences using Dollond equatorial telescopes; and Fernandez and Marquez to measure angular positions and height of the solar prominences.

They successfully carried out the programme under clear skies. Marquez and the Portuguese delegation published reports of this expedition.[9] In conclusions that contradicted the rest of the astronomical community, Marquez supported the optical theory and, despite not considering it decisive in the controversy about the solar phenomena, regretted not using photography.[10]

The Expeditions of the Madrid Observatory and the Involvement of Secchi

The Expedition to Moncayo and Tarazona

The Madrid Observatory organised an expedition to Moncayo, near Zaragoza. Eduardo Novella, first astronomer at Madrid Observatory led this expedition which included: Tomás Ariño, assistant at Madrid Observatory; Manuel Saenz Díez, professor of chemistry at the Central University (Madrid); Constantino Ardanaz, road engineer; Valero Causada, professor of physics at the University of Zaragoza and Celestino Olózaga, student from the school of road engineers.

Novella's party was joined by many other observers, including a French expedition,[11] prepared by Hervé Faye and guided by Urbain Leverrier, director of the Paris Observatory, plus other members from the same observatory: Yvon Villarceau, first astronomer; Jean Chacornac and Léon Foucault, astronomers; Mr Cutant, mechanic. Egyptian astronomer Ismail Effendi Mustafa, who had been trained at the Paris Observatory and worked at the

[9] See, respectively: Marquez, *Memoria sobre el Eclipse*, and Commissão Portugueza, *Eclipse Solar de 18 de Julho de 1860* (Coimbra: Imprensa da Universidade, 1860).
[10] Marquez, *Memoria sobre el Eclipse*, 93-94.
[11] Eduardo Novella, *Informe de lo Ocurrido en la Expedición que Fué al Moncayo á Observar el Eclipse de Sol del 18 Julio Último* (Madrid: Imprenta Nacional, 1860), 3-4.

national Egyptian observatory in Cairo, went to Spain at his own expense.[12] Together with geodesist Nicolas August Tissot from the Ecole Polytechnique, they planned observations, sending some observers to nearby Tarazone to minimize the risk of clouds.

According to the joint observation programme, astronomers divided the eclipse work between the two stations. At Moncayo, photography appeared to have dominated with Manuel Saenz Díez, Tomás Ariño, Valero Causada, and Celestino Olózaga assigned to the task. Meanwhile, Yvon Villarceau and Jean Chacornac handled measurements of the angular positions of the prominences and Ismail Effendi performed observations of the contacts. Muñoz oversaw meteorological observations. Cutant managed the chronometers. At Tarazona, Urbain Leverrier and Constantino Ardanaz handled measurement of angular positions of the prominences. Léon Foucault did photography, Tissot looked for an intra-mercurial planet, and Novella focussed on the solar corona. Sanz managed the chronometers. Novella published the results in a report to Gil de Zárate.[13] Clouds in Moncayo thwarted photography, but the programme otherwise went as planned and they correctly concluded that the solar phenomena observed during the eclipse (prominences and corona) were pertaining to the Sun.[14]

The Expedition to Desierto de las Palmas

Aguilar led the Spanish expedition to Desierto de las Palmas, a Carmelite monastic complex near Castellón de la Plana. This site had been previously used by François Arago as a triangulation station related to the extension of the French Meridian to the Balearic Islands in 1806-1807.[15] For the eclipse observation plan, Aguilar consulted with Angelo Secchi, Jesuit and director of the Collegio Romano Observatory.[16] Secchi's interest in the application of new techniques in astronomy focused the investigation of astrophysical questions. Aguilar invited Secchi to join the Spanish expedition due to both his interest in solar studies and complexities of the Italian political context.[17]

There was a small Italian expedition that observed the eclipse from Torreblanca, near Oropesa. It included astronomers Francesco Carlini (and his wife Gabriella Carlini (née Sabatelli)) from Milan (Brera) Observatory; Giovan Battista Donati, Ernst Wilhelm Tempel, and custodian Ulisse Marchi (in charge of meteorological observations) from Florence

[12] Daniel A. Stoltz, *The Lighthouse and the Observatory* (Cambridge: University Press, 2017).
[13] Novella, *Informe de lo Ocurrido en la Expedición*.
[14] Ibid., 10
[15] Pierre Bayart, "La Méridienne de France et Sa Prolongation Jusqu'aux Baléares," *Revue XYZ* 116 (2008): 58-62.
[16] Ten et al., "José Monserrat y Riutort," 4 and 15.
[17] Ibid.

Observatory; and a Pisan mathematician, Ranieri Simonelli, who collaborated with Donati on photographic operations. As requested by the Spanish government, they were accompanied by José Bonet, professor of Nautic in Barcelona, who brought his twelve-year-old son. Amateur astronomer Tommaso Simonelli also joined the expedition. The party planned to photograph eclipse totality, but captured only the partial phases.[18]

Growing tensions between the Italian Government and the Papal State complicated Secchi's participation in this Italian expedition. Instead, Cardinal Vincenzo Santucci, who presided over the Papal Congregation, approved Secchi joining the Spanish expedition at Desierto de las Palmas, near Castellón de la Plana and granted two hundred ecus towards travel expenses. Pope Pius IX, himself an amateur astronomer who supported the Collegio Romano Observatory, also endorsed Secchi's mission, one that likely carried political significance. Sending Secchi on an international expedition as an official representative of the Papal State reaffirmed its existence and global visibility at a time when the political situation endangered its existence. The process of political unification in Italy was ongoing: many territories had already been annexed and properties confiscated by the Italian government.

Aguilar's expedition party also included astronomers Cayetano Aguilar, from Madrid Observatory; José Monserrat y Riutort, Professor of Chemistry at Valencia University (with some students); Dionisio Barreda Fernandez, Professor of Physics at Salamanca University; fr. Juan Vinader SJ, Professor of Physics at Salamanca Seminary with his assistant, Pablo Orellana; Antonio Rodriguez de Cepeda Garrido, a wealthy lawyer, Professor of Political Economy at Valencia University and amateur astronomer; Federico Maria Botella y Hornos, mining engineer, Angel Mayo, road engineer and Mr Alcover, engineer. Other participants are not mentioned in the reports and remain unidentified. From the Collegio Romano Observatory, Secchi brought the Cauchoix telescope, equipped with two *camera obscurae*, as well as a chronometer, an aneroid barometer, two thermometers, a Melloni thermomultiplier, a Jones magnetometer and some polariscopes. The Madrid Observatory lent a Repsold transit instrument, a 75-mm Fraunhofer telescope, a new-brand 125-mm Steinheil telescope (Novella took another one to Oropesa), a sextant, two Dent chronometers, a Dent pendulum, a Morse telegraph, a Robinson anemometer, some thermometers and barometers. These instruments were purchased by the Spanish government specifically for the expedition[19] with a total expense around 4,000 FF.[20] This substantial expenditure for

[18] Giovan Battista Donati, "Intorno alle Osservazioni Fatte a Torreblanca in Spagna dell'Eclisse Totale di Sole del 18 luglio 1860," *Annali del Reale Museo di Fisica e Storia Naturale di Firenze* 1 (1866): 21-37.

[19] See letter by Aguilar to Secchi: Madrid, 26 January 1860, Archivio Storico della Pontificia Università Gregoriana [APUG], Fondo Angelo Secchi S. I., 10.

[20] The annual salary of an astronomer in France at the end of the nineteenth century was about

equipment perhaps evidences investment in the revitalisation of the Madrid Observatory and, consequently, Spanish astronomy. Amateur astronomers who joined the expedition provided additional instruments such as a 93-mm Lerebours telescope and a transit instrument with prism eyepiece.

Figure 2 - The Spanish party at Desierto de las Palmas, before moving to San Miguel. Secchi is recognisable around the middle, indicated by the letter "c". Source: "Eclisse totale del sole del 18 luglio 1860", I.D.3, B. 90, 213, Archives of INAF - Osservatorio Astronomico di Roma. Courtesy of INAF - Osservatorio Astronomico di Roma.

The transit instrument and the photographic apparatus were set up in one of the hermitages of the Carmelite complex. Despite great difficulty, an astronomical station was installed in a very small chapel (San Miguel) on a nearby crest. Secchi found the site altogether

300 FF.

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ill-suited to observation and regretted that it had not been inspected in advance.[21] Not only surrounded by mountains, observers saw atop those mountains clouds caused by evaporation and condensation of seawater in the coastal location.

Secchi's travel notebooks and correspondence reflect his anxiety about the weather, ongoing discomfort with the accommodations, and inconveniences related to the instruments.[22] Although clouds initially obscured observations on eclipse day, most of the phenomenon was well visible and the investigations could be conducted as planned.

As in Moncayo and Tarazona, astronomers divided the labour of observing the eclipse. At Carmel hermitage, Monserrat and some of his students handled preparation of the darkroom and materials for the photographic operations. Fr. Juan Vinader, Professor of Physics at Salamanca Seminary, acted as guide of the Cauchoix telescope. Dionisio Barreda, Professor of Physics at Salamanca University, performed spectroscopic and polariscopic observations to study possible variations of the solar spectrum during the eclipse.[23] Various amateur astronomers along with C. Aguilar and Alcover made drawings of the corona and records of visible stars.

At St. Miguel chapel, visual observations appeared to dominate the programme and were to be performed by Prof. A. Aguilar with the Steinheil telescope, Mr. Cepeda with a Lerebours telescope, and Fr. Secchi with a Fraunhofer telescope. Botella and Mayo handled meteorological observations, thermopile measurements, and declinometer observations.

Solar Photographs Taken at Desierto

The main result of the expedition was the photographic record of various phases of the eclipse. A total of fourteen photographs were taken during the partial phases and five during the totality, one was discarded because of poor quality. The four photographs showing totality were taken with exposures from 6 to 30 seconds. The corona was just slightly visible in the collodion plates. Although these photographs have been later attributed to Secchi,

[21] Ileana Chinnici, *Decoding the Stars: A Biography of Angelo Secchi, Jesuit and Scientist* (Leiden: Brill, 2019), 117-125.

[22] Ileana Chinnici, *Appunti di un Gesuita Scienziato. I Diari di Viaggio di Angelo Secchi SJ 1860-1875* (Florence: Olschki, 2022), 1-33.

[23] These first spectroscopic observations of a total solar eclipse were not sufficiently analyzed; see Angelo Secchi, *Relazione delle Asservazioni Fatte in Spagna Durante l'Eclisse Totale del 18 Luglio 1860* (Roma: Tipografia delle Belle Arti, 1860), 39. According to some sources, an unpublished manuscript is preserved at Madrid Observatory, a copy of which has been requested, but nor received by the time of publication; a summary is in Antonio Aguilar, "Eclipse de Sol del 18 de Julio de 1860", *Anuario del Real Observatorio de Madrid* 2 (1860): 231-232; see Ten at el. "José Monserrat y Riutort," 19. Some results were mentioned in Mädler's report (see below).

coeval sources clearly state that they were taken by José Monserrat.[24] This misattribution is perhaps because Secchi proposed the photography and supervised the preliminary tests. Further, his Cauchoix telescope was the one used for the photography. Secchi's role as lead astronomer of the expedition may also have overshadowed the name of Monserrat, and his co-production of this result.[25]

Despite a misunderstanding between Secchi—who had advised a portrait objective—and the photographer Montserrat who used a landscape objective instead,[26] they nonetheless captured the solar corona and the prominences precisely enough to determine their number and shape. These details were collected in a drawing. The most important result was the conclusion that prominences and corona are phenomena pertaining to the Sun, as predicted by the so-called topographic theory.

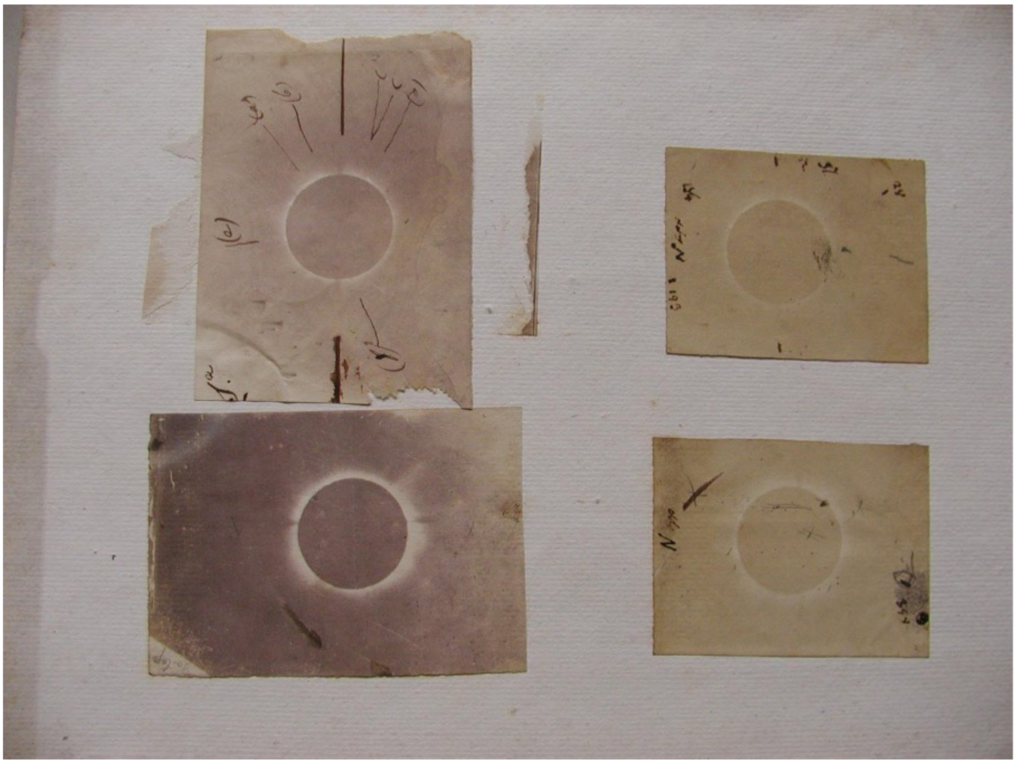

Figure 3 - The four photographs of the totality taken at the Desierto. Source: Source: "Eclisse totale del sole del 18 luglio 1860", I.D.3, B. 90, 213, Archives of INAF - Osservatorio Astronomico di Roma. Courtesy of INAF - Osservatorio Astronomico di Roma.

[24] Ten at al. "José Monserrat y Riutort."

[25] Jesús Ildefonso Diaz Diaz, "La primera Fotografía de las Protuberancias Solares Fue Hecha en España. El Eclipse de Sol de 1860 y la Real Academia de Ciencias," *Revista de la Real Academia de Ciencias Exactas, Físicas y Naturales de España* 107 (2014): 9-42.

[26] Secchi, *Relazione delle Asservazioni*, 22.

A detailed expedition report was sent to the Académie des Sciences in Paris. Other reports were later published in the *Anuario del Real Observatorio de Madrid* and in the *Memorie dell'Osservatorio del Collegio Romano*.[27] These reports attribute the photographs to Monserrat.[28] Secchi also praised the work of the Spanish colleagues who obtained good solar photographs without having any expertise in astrophotography.[29] Aguilar exchanged copies of the photographs to other astronomers, including Warren De la Rue, member of the British expedition. The topographic theory was definitively proved only after the comparison of the photographs taken by the Spanish and the British expeditions.[30]

The British Expedition

As demonstrated above, the single event of a total solar eclipse provided opportunities for astronomers to make a wide range of different types of observations. This approach was also embedded within the organisation of the British expedition in 1860 as each of the participating astronomers were requested to specify the type of observations they were going to make. This had the dual aim of implementing a division of labour among the group and legitimising the participation of party members in a government funded venture, as will be explored further below. The archival materials include an organisational chart that Astronomer Royal George Airy used to structure and visualise the variety of specified observations. Airy's chart lists the observers and their categories of observation divided into five major sections: Astronomy, Photography, Meteorology, Polarization, and Faculae.

Many of these sections were further divided. Astronomy, for example, was subdivided into Elevation of Prominences, Angle of Prominences, Times and General observations.[31] Further notes were added for specific observers who focused on the appearance of the eclipse, for example: the colour of the prominences, the dimensions of the solar corona, and the general landscape around the observing stations. Photography was further subdivided into the Corona & Prominences and observations of "Skylight." Meteorology included subsections for observations of "Air" as well as observations with thermometer and actinometer.

[27] Aguilar, "Eclipse de Sol."
[28] Aguilar, "Eclipse de Sol," 212-213; Secchi, *Relazione delle Asservazioni*, 10, 20.
[29] Secchi, *Relazione delle Asservazioni*, 26.
[30] See letter by De la Rue to Aguilar: [London], 7 November 1861, Archivo Historico del Observatorio Astronomico Nacional Madrid 2/ 2, R. 220 "Correspondencia con Angleterra 1860-1880," accessed October 2025 via carolina.oan.es.
[31] List of Observers and Classes of Observations, 1860 Solar Eclipse, RGO 6/123, folio 88, Royal Greenwich Observatory Archives [RGO], Cambridge University Library [CUL].

The red prominences were frequently the subject of these further divisions. The observations of red prominences and photographic observations were two of the most dominant concerns. Airy stated in 1860 that the appearances of the red prominences were observations "specially requiring attention."[32] A consideration of how Airy believed these two goals would be achieved shows why red prominences were the primary research goal, how Admiralty support led to exclusionary practices, and how the secondary research goal of photography unexpectedly revealed larger astronomical networks and invisible labour.

Red Prominences

The primary goal of the 1860 British expedition was to settle the question of the red prominences, first reported in the total solar eclipse of 1842, and seen again in 1851. The source of the red prominences had so far eluded astronomers.

In 1842, Francis Baily travelled to Pavia for the eclipse and unexpectedly saw "three large protuberances," pink or lilac in colour, emanating from the disk of the Moon during the eclipse. These "red mountains" lasted for the duration of totality.[33] At the same time, Airy, who travelled to Turin to observe the eclipse with his wife Richarda, saw "some small red flames," like saw-teeth, at the bottom of the eclipse,[34] although he cast some doubt on his observations due to the dark clouds intermittently covering the Sun. Richarda reported that these red flames could even be seen with the naked eye.[35]

These reports significantly increased interest in eclipses among British astronomers, particularly for the next total eclipse visible over Europe. In response, the British Association for the Advancement of Science (BAAS) produced suggestions for observing the eclipse of 1851.[36] This guide, primarily drafted by Airy, particularly emphasised observations of the corona and "the rose-coloured prominences (seen so markedly in the eclipse of 1842," noting that "it seems highly desirable that the arrangements for observation should be planned with especial reference to them."[37] If the prominences belonged to the Sun, it

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[32] The Astronomer Royal, "Total Eclipse of July 18, 1860," *MNRAS* 4, no. 2 (1859): 63.
[33] Francis Baily, "Some Remarks on the Total Eclipse of the Sun, on July 8th, 1842," *MNRAS* 15 (1846): 6.
[34] George Airy, "Observations of the Total Solar Eclipse of 1842, July 7 (July 8, civil reckoning)," *MNRAS* 15 (1846): 15-16.
[35] Richarda Airy was later confirmed as the "companion" quoted in ibid.: 16. Her complete account appears in RGO 6/112, folio 64, CUL.
[36] John Herschel, George Airy, James David Forbes and Baden Powell, "Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851," in *Report of the Twentieth Meeting of the British Association for the Advancement of Science* (London: John Murray, 1851): 359-372.
[37] Ibid., 361.

would "indicate physical peculiarities of structure on a most stupendous scale, and perhaps of corresponding importance.".[38] Unfortunately, clouds significantly impacted observations by British parties of the total solar eclipse in 1851. While most observers suggested a solar origin for the prominences, uncertainty caused by the weather left the matter unsettled. Still no closer to a clear resolution, investigation of the red prominences became a top priority for the 1860 eclipse.

Who Is Allowed on These Expeditions?

While the 1860 expedition is generally considered the first organised effort by British astronomers to observe an eclipse, there was an earlier British eclipse expedition, organised by Airy in 1851.[39] Dozens of British astronomers travelled to Sweden and Norway, aided by Airy's efforts to secure passports, lodgings with local diplomats, and duty-free transport of instruments. The Admiralty even provided a small grant covering the costs for Airy and an assistant, Edward Dunkin, to mount the expedition.[40] However, they stopped short of providing a steam ship for the journey, requiring observers to arrange private passage.[41] Due to this support, Airy considered his team as "agent[s] of the British government."[42] Unfortunately, clouds affected nearly every observation station, likely resulting in the historiographically diminished status of Airy's 1851 expedition. However, the diplomatic success of the expedition set a precedent for state support of future eclipses.

As he had in 1851, Airy approached the Foreign Office for support for the expedition. In his application he stated that the upcoming eclipse was "astronomically and cosmically, of great importance".[43] Airy was well positioned to conduct these negotiations given that as Astronomer Royal his work at Greenwich was overseen by the Admiralty, which resulted in regular interactions with governmental bodies for the Observatory to receive "regular and substantial" government support.[44] The Admiralty again played a particularly significant

[38] Ibid.

[39] For a general overview of the British eclipse expedition enterprise, see Alex Soojung Kim-Pang, *Empire and the Sun: Victorian Solar Eclipse Expeditions* (Stanford, CA: Stanford University Press, 2002).

[40] Admiralty grant application: George Airy to The Rt. Hon. Sir FT Baring, Bart, 12 May 1851, RGO 6/74, folio 25-26, CUL, and approval: Parker to George Airy, 19 May 1851, RGO 6/74, folio 29, CUL.

[41] F Beaufort to George Airy, 21 May 1851, RGO 6/74, folio 31, CUL.

[42] Instructions to Mr. Dunkin, 16 July 1851, RGO 6/119, folio 71, CUL.

[43] George Airy to the Secretary of State for the Foreign Department, 22 Feb 1860, RGO 6/123 folio 4-8, CUL.

[44] Jessica Ratcliff, *The Transit of Venus Enterprise in Victorian Britain* (London: Pickering & Chatto, 2008), 30-31.

role in the 1860 British eclipse, most tangibly in the supplying the HMS *Himalaya* to transport the expedition parties to Spain.

Crucially, Airy created a new standard for expedition party members in light of the increasing Admiralty support. Airy saw himself as "representing the Admiralty" and aimed to minimize unnecessary expenses for the Admiralty through restricting who would get a place on the *Himalaya*.[45] In applications, he looked for those who had both a plan and familiarity with instruments that facilitated "efficient scientific observation".[46] Records of correspondence with potential observers are littered with examples of rejections or requests for further detailed plans by Airy written to those he believed were just hunting the picturesque.[47] For example, a letter from Airy to H. A. Goodwin stated that "[i]t is the wish of the Admiralty to give the advantage of conveyance by a first-class steam ship to observers of the Solar Eclipse who are prepared with definite plans of observation such as may be useful to science. If you will favor me with a statement of your intentions on this point, I shall be prepared to transmit to you further information."[48]

When corresponding with the Admiralty, Airy also justified the participation of his and Warren De la Rue's wife, Georgiana De la Rue (née Bowles), emphasising their previous assistance with their husbands' investigations. To the initial list of observers submitted to the Admiralty, Airy appended a note: "if circumstances should permit, I should be glad to offer passage to two ladies, vizt., My Wife (who was my companion at the Total Eclipse of 1842), Mrs De la Rue (who I believe aids her husband in photography)".[49]

The gravitas of the Admiralty's backing not only meant that observers had to have more formal and definite scientific agendas for their observations, but it also shaped the list of people chosen for the expedition. The new standards begin to privilege a more restricted set of observers that would feature in government-supported expeditions across the century. This contributed to the exclusion and devaluation of eclipse observations from people outside of this group, such as women and local workers. While some of the women who participated in the expedition were involved with the observational work, only Richarda, the wife of the Astronomer Royal, had her observation reports included in the final published

[45] George Airy to C Marett, 20 June 1860, RGO 6/124, folio 240, CUL.

[46] George Airy to Joseph Beck, 12 May 1860, RGO 6/123, folio 160, CUL.

[47] See for example George Airy to C Marett, 20 June 1860, RGO 6/124, folio 240, CUL; George Airy to Charles Pritchard, 26th June 1860, RGO 6/124, folio 357, CUL.

[48] George Airy to Rev. HA Goodwin, 19 June 1860, RGO 6/124, folio 64, CUL.

[49] George Airy to Lord Clarence Paget, 1 May 1860, RGO 6/123, folio 20-23, CUL. Four women would eventually participate in the 1860 eclipse (Richarda Airy, Hilda Airy, Mary/Marie Struve and Mary Jane Vignoles).

report.[50] The British 1860 expedition further highlights the deep connections between the scientific goals, the funding structures and the social milieu of British eclipse expeditions.

Photographic Networks

Photography did not become a research goal for the 1851 eclipse *expeditions*, but the BAAS recommended that fixed observatories along the path of the eclipse attempt "Daguerreotyping or Talbotyping the image of the sun."[51] Airy tried to persuade Henry Fox Talbot to photograph this eclipse, but Talbot was both unsure of the best method and worried that photography would require the complete focus of the observer "thereby losing the rare opportunity of studying the rose coloured eminences."[52]

Subsequent British efforts to photograph the corona in 1860 were largely led by Warren De la Rue.[53] He had been inspired by a daguerreotype of the Moon created by John Adams Whipple and George Phillips Bond at the Harvard College Observatory and displayed in 1851 at the Great Exhibition, where it won a medal. De la Rue then began to use the new wet collodion process—a more light-sensitive method capable of sharper detail that also could produce multiple prints from the same plates—to capture images of the Moon. His attention later turned to photographing the Sun, for which he designed a photoheliograph used to take daily solar photographs at Kew Observatory.[54]

Still, it took a trip to Russia to peak De la Rue's total solar eclipse ambitions. In 1858, De la Rue visited Johann Heinrich von Mädler in Dorpat, now Tartu and Robert Luther in Königsberg. There, he saw in person the inspiring image Berkowski produced in 1851.[55] These meetings alerted De la Rue to the upcoming eclipse and the limitations of daguerreotype for capturing a solar corona.

Not only did his broader connections set De la Rue on a path towards eclipse photography, but they were also essential for the physical necessities of eclipse photography, including

[50] George Airy, "Account of Observations of the Total Solar Eclipse of 1860, July 18, made at Hereña, near Miranda de Ebro," *MNRAS* 21, no. 1 (1860): 1-16.

[51] Warren De la Rue, "XVIII. The Bakerian lecture—On the Total Solar Eclipse of July 18th, 1860, Observed at Rivabellosa, near Miranda de Ebro, in Spain," *Phil. Trans. R. Soc.*, 152 (1862): 364.

[52] HF Talbot to George Airy, 2 May 1851, RGO 6/119, folio 500-501 CUL.

[53] For more on De la Rue and photography, see Holly Rothermel, "Images of the Sun: Warren De la Rue, George Biddell Airy and Celestial Photography," *The British Journal for the History of Science* 26, no. 2 (1993): 137-169.

[54] David Le Conte, "Warren De la Rue – Pioneer astronomical photographer," *The Antiquarian Astronomer*, no. 5 (2011): 14-35; Margaret Huggins, "Obituary: Warren De la Rue," *The Observatory*, 12 (1889): 245-250.

[55] De la Rue, "XVIII. The Bakerian Lecture," 333-334.

transportation of instruments and construction of dark rooms in the zone of totality. Also essential was support from governments both sending and receiving eclipse observers. In correspondence with the Consul General for Spain, Airy used the materiality of eclipse photography as justification for requiring additional special customs accommodations for supply cases. He highlighted how the photographic plates would be "entirely rendered useless" if exposed to the light and requested the required government inspection take place in London instead.[56]

De la Rue was further aided by a group of individuals who made observations. They were immortalised in photographs taken at the observing station, in engravings created from those photographs, and within his report of the expedition (as demonstrated in Figures 4, 5 and 6). All of these media create selective representations of who participated in which parts of the work. Figure 4 shows De la Rue inside the observing hut with Reynolds, Clark, Downes, and Beckley, all of whom were described as participating in the work. However, De la Rue's dramatic description of the observations mentions Juan, a local labourer, for accidentally starting a small fire while smoking glass for bystanders to safely watch the eclipse.[57] The story implies that Juan assisted with observations, although he is absent from Figure 4 and never mentioned beyond this anecdote. Juan possibly appears (front row, first on the right) in Figure 5, a group photograph taken during Airy's site visit that shows a larger number of people outside the observing hut. This photograph portrays a more accurate amount of labour involved in these expeditions, even if there are very minimal written records that discuss this.

Differences in Figures 4, 5 and 6 make more explicit exclusionary practices involved when astronomers produced expedition narratives. In Figure 6, De la Rue's figure replaces that of an unidentified woman standing beside Airy in Figure 5. This was edited because De la Rue thought he looked ungraceful in the original photograph. It centred him next to Airy, emphasizing his key position at the station. Ultimately, only figures 4 and 6 were published.[58] These examples additionally underscore that, although over time De la Rue's name is attached to the photographic observations, the observations relied, as expected, on a larger group of individuals than those mentioned in the published accounts. Individuals were strategically included and excluded from the different representations of the expedition.[59]

[56] George Airy to Consul General for Spain, 21 May 1860, RGO 6/125, folio 6-7, CUL.
[57] De la Rue, "XVIII. The Bakerian Lecture," 353-354.
[58] Warren De la Rue, Notes on the Total Solar Eclipse of 18th July 1860, Rivabellosa, RGO 73, CUL.
[59] See also Ana Simões, "In the Shadow of the 1919 Total Solar Eclipse: The Two British Expeditions and the Politics of Invisibility," *Berichte zur Wissenschaftsgeschichte* 45, no. 4 (2022): 581-601; Steven Shapin, "The Invisible Technician," *American Scientist* 77, no. 6 (1989): 554-563.

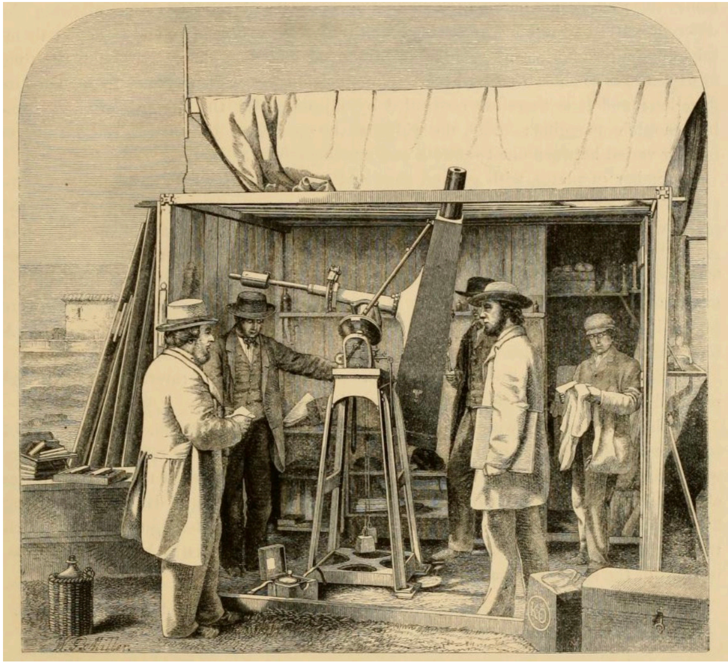

Figure 4: Warren De la Rue and some of his photography assistants, Rivabellosa, 1860. Source: Warren De la Rue, "XVIII. The Bakerian lecture—On the Total Solar Eclipse of July 18th, 1860, Observed at Rivabellosa, near Miranda de Ebro, in Spain," 363. Courtesy of The Royal Society.

Figure 5: Photograph of some of the expedition party, on account of George Airy's visit, Rivabellosa, 1860. Source: Joseph Bonomi 1860 Expedition Scrapbook, Add MS 56, Royal Astronomical Society. Reproduced with permission of the Royal Astronomical Society.

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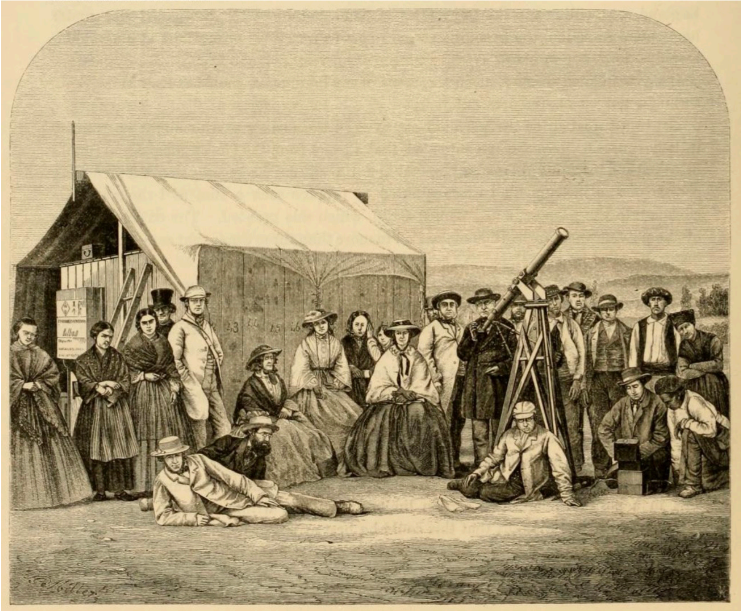

Figure 6: Altered engraving of expedition party, Rivabellosa, 1860. Warren De la Rue, "XVIII. The Bakerian Lecture—On the Total Solar Eclipse of July 18th, 1860, Observed at Rivabellosa, near Miranda de Ebro, in Spain," 336. Courtesy of The Royal Society.

France/Algeria

At the end of 1859, Urbain Le Verrier (1811-1877), then Director of the Paris Observatory, wrote a letter to his Minister of Public Instruction (Ministère de l'Instruction Publique). It stated that it was France's duty to organise expeditions for the solar eclipse of 1860 for two reasons: firstly, because of the country's proximity to Spain, and secondly, because of the French possessions in North Africa.[60]

The French government therefore set up two types of expedition in 1860: expeditions to Spain, financed by the Ministry of Public Instruction, prepared mainly by Hervé Faye (1814-1902) and finally directed by Le Verrier;[61] and to Algeria, organised by the Ministry of War (Ministère de la Guerre).

[60] Le Verrier to Rouland, 17 December 1859, F17/3726, French National Archives.

[61] The first project: Hervé Faye, "Sur l'Éclipse Totale de Soleil du 18 Juillet Prochain", *Comptes Rendus Hebdomadaires des S*éances *de l'Académie des Sciences* [*CRAS*] 59, (1859): 564-71; Hervé Faye, "Sur l'Éclipse Totale de Soleil du 18 Juillet Prochain (Deuxième partie)," *CRAS* 59, (1859): 594-600. For Le Verrier's reaction, see Alexandre François Hureau De Senarmont, "Monsieur le Président Donne Connaissance d'une Lettre de M. Le Verrier. . .," *CRAS* 59, (1859): 996.

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The French occupation of Algeria began in June 1830 with the massive landing of 30,000 French soldiers on the coast near Algiers. After a few days of fighting, Algiers was taken. The French army first occupied the "Regency of Algiers," i.e. the Bet-el-mal which was the westernmost province of the declining Ottoman Empire. The territories occupied expanded: rapidly to the east and west along the Mediterranean coast, but also southwards from the 1840s onwards. Algeria was considered part of the French national territory by the French from 1848, with its three departments of Algiers, Oran and Constantine. In 1860, the French occupied the Saharan frontiers, close to the ancient Roman limes.

Most of the "natives" were French subjects, inhabitants of the French departments of Algeria (after 1848) but not citizens. They did not have the same rights as the native population of metropolitan France. The few indigenous French citizens were those who had renounced their personal status, linked to the customs of the Muslim religion. Algeria's settlers were Europeans (Mediterranean but also German), a little over half of whom were French at the beginning of the twentieth century. By 1860, Algiers had changed since the French invasion: the old town, the medina (known as the Casbah), was now surrounded by European-style buildings.[62]

The Algiers Astronomer

From the start of the occupation, the Ministry of War oversaw the Algerian territories. The only administration that escaped military control was school, under the authority of Public Instruction. From 1858 to 1861, Napoleon III, under pressure from Algerian colonists and Saint-Simonian circles, created a Ministry for Algeria. His cousin, Napoléon-Jérôme Bonaparte, became its ruler. By decree, he founded an observatory in Algiers and, in 1860, ordered its astronomer to observe the eclipse of July. The minister relied on the support of the Governor General of Algeria, the local administrator of the colonised territories, who was an army officer. The meteorological and astronomical observatory was soon run by Charles Bulard (1825-1905), sent from Paris in 1859. A self-taught meteorologist and astronomer, he had lived and observed in England until he was recruited by the Paris Observatory. He arrived in Algiers with a 33cm diameter Foucault reflecting telescope, one of his first designed by the Parisian physicist.

Bulard was sent from Paris by the Minister to study "physical astronomy," mainly planetary surfaces. He also had to organise a government meteorological network in Algeria. He tried to use this network to broadcast the observatory's time throughout Algeria and even

[62] James McDougall, *A History of Algeria* (Cambridge: Cambridge University Press, 2017), see chapter 2 and 3; Jennifer E. Sessions, *By Sword and Plow. France and the Conquest of Algeria* (Ithaca and London: Cornell University Press, 2011).

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Tunisia, using the telegraph. In 1861, the observatory was set up on the hill of the nearby village of El-Biar, about 4 km from the port. [63]

On 12 July 1860, the August issue of the *Revue Africaine* was distributed in Algiers. This review, founded in 1856, was the culmination of the intellectual output of the Algiers colonists. This early distribution was explained by one of the articles in the issue: a presentation of the solar eclipse of 18 July by Bulard. "As this work is intended above all for the general public, the author has endeavoured, as far as possible, to avoid technical language, which would have been understood only by those initiated into astronomical knowledge."[64] After identifying the best observation sites for residents of major Algerian cities, he goes on to describe the circumstances surrounding the phenomenon in Algiers.

He makes the observation a test for the public hour in the country:

> "It will therefore be a good opportunity for Algerians to find out, once in their lives, what time it really is; because, until now, it must be admitted, despite the quality of certain clocks in our main towns and the commendable names of certain builders engraved on their dials, these clocks do not indicate the time in the places where they are located, as they are not run by competent men, and also because of the absence of railways and electric telegraphs that work equally well. . . Moreover, these times of chronometric chaos are about to end. . .".[65]

This announcement of the end of the chronometric chaos served the interests of the astronomer. He thus took part in a polemic on Algerian time in the daily press.[66]

On 13 July, the day after the *Revue Africaine* was circulated in intellectual circles in Algiers, the colony's daily newspaper, *L'Akhbar*, also published an insert presenting the eclipse with

[63] Lewis Pyenson, *Civilizing Mission*: *Exact Sciences and French Overseas Expansion, 1830–1940* (Baltimore and London: Johns Hopkins University, 1993); Frederic Soulu, "Développement de l'Astronomie Française en Algérie (1830-1938): Astronomie de Province ou Astronomie Coloniale ?" (PhD diss., Université de Nantes, 2016).

[64] "Ce travail étant surtout destiné au public, en général, l'auteur s'est attaché, autant que possible, à éviter le langage technique, qui n'eût été compris que par les personnes initiées aux connaissances astronomiques." Charles Bulard, "Notice sur l'Éclipse Totale de Soleil du 18 Juillet 1860 Visible en Espagne et Algérie," *Revue Africaine* 23, (1860): 375.

[65] "Ce sera donc une bonne occasion pour les Algériens de savoir, une fois dans leur vie, l'heure qu'il est réellement; car, jusqu'à présent, il faut l'avouer, malgré la qualité de certaines horloges de nos villes principales et les noms recommandables de certains constructeurs qu'elles portent gravées sur leurs cadrans, ces horloges n'indiquent point l'heure des endroits où elles sont situées, n'étant point dirigées par des hommes compétents, et aussi par suite de l'absence de chemin de fer et de télégraphes électriques fonctionnant également bien. . . .Au reste ces temps de chaos chronométriques vont cesser." Bulard, "Notice sur l'Éclipse Totale de Soleil," 587-588.

[66] *Akhbar* 3050, Sunday 1st July, 1860.

plates relating to the total eclipse of the Sun.[67] The source is identical, the government astronomer Bulard. Finally, Bulard published a Notice, in the form of a 16-page in-8° brochure with two plates, on sale in bookshops at the moderate price of 50 centimes. 4,000 copies were sold. This print run is of the same order of magnitude as that of the colony's press issues (Moniteur, Akhbar, Atlas). Crowds in Algiers and across colonised Algeria watched the phenomenon.[68]

Observing in Lambessa

Two scientific expeditions observed the eclipse of 18 July in Algeria: one sent from Paris by the Minister for War and organised from his prestigious school for scientific officers, the Ecole Polytechnique; the other sent from Algiers by the Minister for Algeria, with Bulard the astronomer from his observatory. We will focus on the material conditions of this second expedition. However, it gives us a great deal of information about the first expedition, which joined it in sharing the observation site.

This observation site is the town of Batna, at the foot of the Aurès mountain range. The French established a military camp in 1844, and later a new town, Batna, to control the Sahara route. It is ideally situated on the central line, i.e. the path of the maximum duration of the phenomenon, one of the furthest south of the sites controlled by the army. To reach it, Bulard left Algiers by boat and travelled along the coast to Philippeville.[69] Overland transport was still unsafe outside the major towns. The learned officers from Polytechnique arrived from Marseille at the same port. Bulard joined the troops who had come to fight the insurrections in Kabylia.[70] The astronomers were escorted to Constantine, centre of power for the east of the country, then left for Batna. They arrived on 6 July, 1860. Bulard established himself in Lambessa,[71] just a few kilometres south. This village near Batna is an archaeological site that has been excavated since 1848 by the military engineers. A penal colony was established there in 1850.

All the reports thanked the Chief of Engineers Charles Mante, who set up two small observatories, one for the Parisian astronomers and the other for the Algiers astronomer. These were wooden huts for the instruments and canvas tents for the men. Pillars were

[67] *Akhbar* 3057, Friday 13 July, 1860, 3.
[68] V. Lambel, "Eclipse Totale de Soleil du Mercredi 18 Juillet 1860", *Akhbar* 3061, Friday 20 July, 1860, 2; Lecouturier, "L'Éclipse Totale du 18 juillet," *Revue Algérienne et Coloniale* 3 (1860): 377-81.
[69] Today Skikda.
[70] Charles Bulard, "Eclipse Totale de Soleil du 18 Juillet 1860, Observée à Lambessa, Province de Constantine," *CRAS* 53 (1861): 509.
[71] Today Tazoult.

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built for the meridian instruments. For Bulard's telescope, a railway was laid to facilitate handling.

During the eclipse, Bulard acknowledged that he owed the success of his installation to the Military Engineers, and the High Command, General de Martimprey, then Commander of the land and sea forces, who "was kind enough to send instructions to the military chiefs of the towns I was to pass through to facilitate the transport of my luggage."[72] Aimé Laussedat (1819-1907), who commanded the team from mainland France and was himself a military officer, explicitly thanked his colleagues from Algeria. In the same article, he lists all the local military personnel who helped the expedition members.[73] Thus, the missions of French astronomers in Algeria relied heavily on the resources of the Army. For most Algerians of native origin, the scientists were hardly distinguishable from the rest of the troops.

Bulard's 33cm telescope was suitable for high-resolution observation of eclipses and sunspots. The mirror of this telescope could be replaced by a non-silvered Foucault mirror, allowing observation of the solar surface at full aperture. It is equipped with a micrometre, which is essential for pinpointing the location of spots or protuberances during eclipses. Bulard's observation of the protuberances at Lambessa in July 1860 was described in detail:

> "As for the protuberances themselves, they were of four kinds: two looked like haystacks on fire caused by a violent wind that blew the flame horizontally. Three others, on the other hand, were perfectly clear-cut and almost geometric: the mottling and shape could only be compared to that of a tulip leaf. Another saw-shaped protuberance was about 27° from the edge of the moon; finally, I noted and followed with the greatest care two small isolated protuberances, as if suspended above the edge of the moon: these, of the brightest pink, were bordered by a very shiny white line which gave them a modelled appearance."[74]

Some of his work was submitted to the Académie des Sciences but never published. For example, in the minutes of the meeting of the Académie des Sciences on 16 September, 1861 published by the journal *Cosmos*, Moigno mentions Bulard's photographs and

[72] Bulard, "Eclipse Totale de Soleil du 18 Juillet 1860," 512.

[73] Aimé Laussedat, "Eclipse du 18 Juillet: Observations Faites à Batna (Algérie). Observateurs: MM Laussedat, Salicis, Mannheim, Bour et Girard: Exposé des Résultats Obtenus," *CRAS* 51 (1860): 441.

[74] "Quant aux protubérances elles-mêmes, elles étaient de quatre sortes: deux présentèrent l'aspect de meules de foin en feu sous l'action d'un vent violent qui aurait entraîné la flamme horizontalement. Trois autres avaient au contraire une figure parfaitement nette et presque géométrique: les marbrures et la forme ne pouvaient se comparer qu'à celles d'une feuille de tulipe. Une autre protubérance en forme de scie régnait sur 27° environ du bord de la lune; enfin j'ai noté et suivi avec le plus grand soin deux petites protubérances isolées, comme suspendues au-dessus du bord de la lune: celles-là, du rose le plus vif, étaient bordées d'une ligne blanche très brillante qui leur donnait un aspect modelé." Bulard, "Eclipse totale de soleil du 18 juillet 1860, observée à Lambessa, province de Constantine." Bulard, "Eclipse Totale de Soleil du 18 Juillet 1860," 511.

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drawings presented by Faye. Some of these graphic documents relate to the report on the Lambessa eclipse. In his note published in the *Comptes Rendus*, Bulard presented this apparently voluminous work.[75] However, these observations were lost during the long process of hierarchical and academic validation.[76] Bulard had also sent drawings to the Royal Astronomical Society in London, where they are still preserved but have not been published.[77] One of them did, however, appear in the press twenty-five years later, illustrating an article on eclipses in which the Sun's corona was exceptionally large.[78]

The military team from Polytechnique school, Laussedat, Professor and Captain of the Engineers, Salicis, repeater and lieutenant in the Navy, Mannheim, repeater and captain of artillery, Bour, repeater and Mines engineer, Girard, curator of scientific collections, studied mainly elusive diffraction fringes and tried to photograph the eclipse totality.[79]

Bulard's observations, published late and incompletely, went unnoticed by his contemporaries. What's more, the astronomer from Algiers did not himself give an opinion on the interpretation of his observations.

North American Expeditions

Scientists in the United States recognised the opportunity of the 1860 total solar eclipse to test the precision of their lunar tables and to realise scientific achievement, perhaps even the discovery of a new planet. They hoped to build both on US observations during an annular eclipse in 1854, and sparse US accounts of eclipse totality in 1858. In early 1860, Simon Newcomb calculated the path and crossing times of the July eclipse that would arc north

[75] Bulard mentions the contents of the report: the drawings, the meridian observations needed to establish the observation station (position and time), meteorological observations and "detailed measurements" taken on the protuberances. Ibid., 509-512.

[76] "Bulard – Note sur l'éclipse de 1860. Comm. MM Babinet, Faye et Delaunay. Envoyé à M Babinet le 27 septembre" Notebook "Mises à l'étude 1856-1863" 397, Archives of the Académie des Sciences.

[77] Thanks to the late William Tobin for pointing out these documents: "45. C. Bulard: drawings of total solar eclipse at Lambessa, 18 July 1860.", MSS Add (Miscellaneous), Royal Astronomical Society.

[78] Camille Flammarion, "L'Éclipse de Soleil du 29 Août," *L'Astronomie* 5 (1886): 426.

[79] Aimé Laussedat, "Observation de l'Éclipse du 18 Juillet; Extrait d'une Lettre de M. A. Laussedat," *CRAS* 51 (1860): 270-271; Aimé Laussedat, "Éclipse du 18 Juillet: Observations Faites à Batna (Algérie). Observateurs: MM. Laussedat, Salicis, Mannheim, Bour et Girard. Exposé des Résultats Obtenus," *CRAS* 51 (1860): 441-445; Aimé Girard, "Observations Photographiques de l'Éclipse du 18 Juillet 1860 Exécutées à Batna (Algérie) par la Commission de l'École Polytechnique," *Revue Photographique* 5 (1860): 317-320; Aimé Girard, "Observations Photographiques de l'Éclipse du 18 Juillet 1860 Exécutées à Batna (Algérie) par la Commission de l'École Polytechnique. Suite," *Revue Photographique* 6 (1861): 9-17; Amédée Mannheim, "Franges Mobiles Incolores Observées Pendant l'Éclipse de Soleil du 18 Juillet 1860," *Annales de Chimie et de Physique* LX, 3e série (1860): 207-210.

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from the Pacific Ocean across the Washington Territory, over what is now Canada, and off the tip of Labrador towards Spain. Newcomb had graduated in 1858 from the Lawrence Scientific School at Harvard and had been working as a computer for *The American Ephemeris and Nautical Almanac.*[80]

The US Congress legislated an American almanac in 1849 to eliminate expenditure to Great Britain and produce its own national almanac that would reference the Washington meridian. They wanted independence from the widespread *British Nautical Almanac and Astronomical Ephemeris*. The first edition of the *American Ephemeris and Nautical Almanac* appeared in 1852 with astronomical data for the year 1855 and maps of anticipated solar eclipses.

With a solar eclipse, the US Nautical Almanac Office could test the precision of its tables for the Moon's position against the *British Nautical Almanac*. An early opportunity came on 28 July, 1851 when a partial solar eclipse was visible in Washington, DC. Observations of contact showed predictions in the British almanac to err by 78 seconds at the start of the eclipse and 62 seconds at the end. The US scientists were thrilled to realise they were only off by 13 seconds and 1.5 seconds, respectively.[81]

To reach the North American zone of totality in 1860 would require significant effort. Railroads did not yet link the east coast and west coast, where Portland wasn't even twenty years old, and settlement had not yet reached Vancouver. The Hudson Bay Company oversaw much of the land in what is now Canada. There were US plans to observe the partial eclipse from extant observatories, and for three expeditions to reach totality.

The westernmost party was led by Naval Lieutenant James Gilliss, founder of the US Naval Observatory, who travelled over five weeks by steamship to reach Washington Territory along with his son, a US Coast Survey assistant. They would observe outside of Fort Steliacoom, just west of the Cascade Mountains. Gilliss had a small assortment of observing equipment lent him for the trip but had no camera. Developing photographs would have posed a tremendous challenge for such a small eclipse party in so remote a location.

Eclipse day dawned clear, with a brilliant early-morning corona. Gilliss reported rosy prominences like those he had observed during the 1858 total solar eclipse in Peru. This second look entirely convinced Gilliss that the prominences were part of the Sun and not

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[80] Deborah Kent, "Shooting for the Moon Benjamin Peirce's Ambitious 19th-century Efforts to Elevate American Mathematics Through Astronomy," *American Mathematical Monthly* July 2025 (forthcoming).

[81] Steven J. Dick, *Sky and Ocean Joined: The U.S. Naval Observatory 1830–2000* (Cambridge University Press, 2003), 132.

the Moon. This party gained neither data nor further eclipse insights, being "... irresistibly drawn to its contemplation. . ." at the expense of scientific observations.[82]

A second small expedition led by Simon Newcomb headed deep into what is now central Manitoba, along the Saskatchewan River. Organised by the American Nautical Almanac Office, Newcomb's party included meteorologist William Ferrel and entomologist Samuel Hubbard Scudder. Newcomb packed a telescope, a sextant, a chronometer, a spy glass, and a polariscope, with hopes to "determine the nature of the mysterious glory, or corona, which surrounds the dark body of the moon."[83]

They travelled overland more than three thousand miles through rugged terrain and changeable weather. The final weeks of the journey by canoe relied on significant local labour, including the expertise of Metís guide George Kipling. After punishing travel, they awoke to thick clouds on 18 July. The unavoidableness of this eclipse pitfall mitigated Newcomb's disappointment.[84] It took another nine weeks to return to Boston with weather observations, natural history specimens, and an appetite for eclipse totality.

Princeton astronomer Stephen Alexander led a party of ten volunteers on a challenging voyage to the northern extremity of Aulezavik Island, north of Labrador. The US Coast Survey lent a steamship for the expedition and this allowed them to transport a camera and necessary accoutrement to attempt eclipse photography. The group had prepared thoroughly and practiced meticulously, but still had to balance the search for a suitable observing site with concerns about a fuel shortage.[85]

At totality, clouds cancelled their search for an intra-Mercurial planet. Just one observer caught a glimpse of the corona, but he was on board the ship while the camera and darkroom had been set up on land. They took twelve photographs during eclipse phases, which assured them that their technique would have captured the corona, had it been visible. Alexander's party made careful records about weather and wildlife, recording vivid descriptions of the cloud colours and sky.

[82] James G Gilliss, "Solar Eclipse – Report of Lieut J. M. Gilliss, U.S.N., on the Results of Observations Made Near Fort Steilacoom, W.T., on the Solar Eclipse of July, in *Report of the Superintendent of the Coast Survey Showing the Progress of the Survey During the Year 1860* (Government Printing Office, 1861), 275-292.

[83] "The Scientific Expedition," *Nor'Wester,* 14 August 1860: 3.

[84] Simon Newcomb, *The Reminiscences of an Astronomer* (Houghton, Mifflin, 1903): 9.

[85] Stephen Alexander, "Solar Eclipse – Report of Prof Stephen Alexander on the Results of the Expedition to Labrador to Observe the Eclipse of the 18th of July, Under Act of Congress approved June 15, 1869," in *Report of the Superintendent of the Coast Survey Showing the Progress of the Survey During the Year 1860* (Government Printing Office, 1861), 229-249.

Reports of successful expeditions in Spain showed what was possible. While American attempts in the field yielded minimal observation of the corona, observers at both a US Coast Survey Station in Gunstock, New Hampshire, and at the Naval Observatory in Washington, DC, recorded valuable information about contact times and sunspot activity. Participants in these US expeditions also collected experience that would prove useful in organising observations of the total solar eclipses in 1869 and 1870, and Transits of Venus in 1874 and 1882. The deepening collaboration between the US Coast Survey, the Naval Observatory, and the American Nautical Almanac Office strengthened ties between astronomical work and federal government support that would undergird future US expeditions.

Conclusion

The location of the total solar eclipse on 18 July 1860 brought an accessible path of totality to a wide variety of astronomical observers operating in a diverse array of geographical, social, and political contexts that shaped the logistics and scientific aims of their expeditions. Existing studies of nineteenth-century eclipse expeditions are often structured from the perspective of the individual nations that furnished financial and logistical support. The parallels between nineteenth-century astronomical expeditions and military exercises combined with actual military involvement in expeditions to observe the 1860 total solar eclipse underscore the sensibility of studying eclipse expeditions with a national orientation. While such investigations certainly illuminate features of each context and expedition, the current innovative and collaborative project enhances this approach by considering together a number of 1860 eclipse expeditions similarly focused on a common set of scientific questions.

As explored above, observers from Britain, France, Spain, Portugal, Italy, Algeria, and North America hoped their 1860 eclipse expeditions would yield insights on the nature and shape of the solar prominences. Many of them shared a hope that photography would prove fruitful on the question. A total solar eclipse provided a special opportunity to test other technologies, too, such as reflecting telescopes and clocks. To varying degrees, observers both in and out of the zone of totality hoped to time the phases of the eclipse and test the accuracy of their lunar tables. They also sought to measure solar radiation and detect both meteorological and geomagnetic variations, as well as measure solar polarisation and radiation.

Considering together expeditions organised by different geo-political entities highlights the variety of factors motivating engagement with similar scientific questions. For the Spanish government, a local eclipse of global interest provided a high-profile opportunity for the newly-revitalized Madrid Observatory to shine. Not only could observers from Spanish observatories contribute to research on the solar corona, but they also could play a prominent role in coordinating the observation efforts of international expedition parties who would visit Spain. For the Papal State, supporting its astronomical star Secchi to join a Spanish expedition staked an international claim for its existence, more so given the separate Italian delegation. The government of France saw eclipse observation as a scientific duty because of both the proximity of Spain and its political claim on Algeria. Similarly in Britain, the Royal Observatory and the Admiralty, saw observing the eclipse as essential to stay at the forefront of scientific inquiry. Meanwhile, in Algeria, Bulard used the eclipse event to engage the Algerian public in an effort to end chronometric chaos. For observers from the United States, a North American solar eclipse was an opportunity to register astronomical achievement on a global scale. They wanted to test the precision of their lunar tables, especially in comparison to British ones, and aspired to the glory of planetary discovery. This multiplicity of motivations for eclipse expeditions comes more clearly into focus through collaborative co-authorship with expertise across various national contexts.

This collective scholarly approach simultaneously reveals the deeply interconnected and collaborative nature of 1860 eclipse expeditions in ways that are otherwise obscured amid nationalist competition, political tensions, and actual military involvement. Notably in Spain, many international actors converged to view the eclipse. Beyond the confluence of observers detailed above, Castellón de la Plana, for example, also hosted groups of Swiss and German astronomers.[86] Tarazona likewise received the Swiss astronomer colonel Emile Gautier.[87] Moreover, even observers at different stations were connected by the central node of Madrid Observatory with Aguilar at the centre of a related correspondence network before and after the eclipse.[88]

The importance of cooperation across the astronomical community in this period is particularly evident in 1860 eclipse photography. The successful output of coronal images both evidenced photography as a tool for astronomical observation and indicated its power for elevating public interest in astronomy. Yet, the ultimate success of this hung on the interconnectedness of a small international community that needed to share information to advance. After the expedition to Desierto, Aguilar sent copies of those photographs to Warren De la Rue, among others. De la Rue and the team in Rivabellosa had also taken photographs of totality that clearly showed the solar prominences. It was the comparison of their photographs with the independent images from Aguilar that ultimately settled the

[86] Emile Plantamour, "Observation de l'Éclipse Totale de Soleil du 18 Juillet 1860 à Castellon de la Plana (Espagne)," *Archives des Sciences Physiques et Naturelles* 8 (1860): 311-322.

[87] Emile Gautier, "Observation de l'Éclipse Totale de Soleil du 18 Juillet 1860, à Tarazona, Aragon," *Archives des Sciences de la Bibliothèque Universelle* 9 (1860): 12-23.

[88] See, for instance, Archivo Historico del Observatorio Astronomico Nacional 2/2, R 175 "Correspondencia con Baviera, Alemania y Prusia".

ongoing debate about the nature of the solar prominences: they were real solar features, not optical effects.[89]

The 1860 event thus demonstrated the ability of new techniques to capture the various phases of a solar eclipse, especially totality, when the chromosphere and corona are visible. This collaborative validation of cameras and spectroscopes as effective tools for eclipse observation expanded the range of research questions for future eclipse expeditions. French astronomers in both Spain and Algeria tested the reflecting telescope, another technical improvement confirmed by the 1860 eclipse. These new developments and emergent scientific questions marked the start of a transition from classical astronomy to astrophysics and heralded a new era of eclipse expeditions. The breadth of this impact across the astronomical community becomes apparent by a global consideration of the 1860 eclipse expeditions.

The above investigations particularly foreground the central role of institutional, especially governmental, structures across these efforts. The enterprise of observing an eclipse is often based from an observatory with a fixed location—such as Paris, Greenwich, Rome, or Washington, DC—yet it usually requires the establishment of a fully-equipped field site in a sometimes distant location, like Spain or Saskatchewan. Eclipse expeditions thus demand the coordination of substantial resources and labour, and often require interacting with a host country as an entity of a geopolitical state. The Spanish government consciously facilitated scientific work from visiting eclipse parties in 1860. They not only arranged free telegraphic connections, waived customs fees, and provided advance diplomatic groundwork, but also informed local authorities and arranged support with the scientific work on eclipse day. They also anticipated a general congress to be held after the eclipse as a venue to discuss findings and share results. Although the congress did not materialise, this institutional coordination combined with the scientific advancements in 1860 nonetheless fundamentally impacted what it meant to host a total solar eclipse.

Events in 1860 similarly shaped the nature of eclipse expeditions. An expedition from Paris was organised by the Ministry of War and explicitly run by the military in light of the relationship between France and Algeria. The Ministry of Algeria, meanwhile, had ordered Bulard to observe the eclipse. Bulard also benefited from the incoming French military engineering resources to support eclipse work in 1860 that facilitated his efforts leading to the 1861 establishment of an observatory in El-Biar. For the British, connection to and support from the Admiralty essentially made eclipse observers state representatives of Great Britain. As lead organiser, George Airy enforced new restrictions and set expectations for expedition participants that thereafter altered the landscape for astronomical communities in the field.

[89] De la Rue, "XVIII. The Bakerian Lecture," 414.

For the United States, the 1860 eclipse activity confirmed the work of the US Nautical Almanac Office and deepened connections between it, the US Naval Observatory and the US Coast Survey, institutions that would prove crucial in subsequent eclipse expeditions. Efforts to observe the 1860 total solar eclipse and related results informed both organisation and funding for subsequent US eclipse expeditions, perhaps most notably for the 1869 total solar eclipse across North America.

Each of these cases individually underscores the importance of state support to execute the complex logistics necessary for a single eclipse expedition, especially involving large telescopes with photographic equipment. Taken together, they illustrate the widespread impact of 1860 total solar eclipse expeditions on protocols for future expeditions in terms of formality and the ways in which eclipse work contributed to the establishment of or validation for support at extant or nascent national observatories. An instance that invites further study is in Egypt, where Khedive Ismail commissioned astronomer Mahmoud Pacha El-Falaki to observe the total solar eclipse in 1860. Related work and attendant publicity contributed to the vitalization of modern astronomy in Egypt and the founding of an observatory in Abbasiya in 1865.

Considering a wider global picture of the 1860 total solar eclipse illuminates the interplay of national interests and institutions with transnational collaborations and joint scientific efforts. While each of the expeditions presented here arose from specific infrastructures in a range of contexts, they nonetheless set a widespread precedent for what would constitute a formal eclipse expedition moving forward. In the decades to follow, the event of a total solar eclipse provided a theatre in which emerging observatories could demonstrate engagement with global astronomy and centre state support.

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