

AT THE DAWN OF AMERICAN ASTRONOMICAL PHOTOGRAPHY: THE TOTAL SOLAR ECLIPSE OF 1869

Jennifer Lynn Bartlett

*Center for Astrophysics | Harvard Smithsonian,
Cambridge, Massachusetts 02138, USA.*

E-mail: jennifer.bartlett@cfa.harvard.edu

Abstract: During the late nineteenth century, techniques that would one day be called astrophysical moved from physics and chemical laboratories into astronomical observatories and challenged the traditional astronomical measurements of positions and brightness. During the same period, the chemical processes of photography revolutionized the recording of astronomical observations, whether traditional or physical. Their entry into mainstream American astronomy was motivated by a quasi-stochastic phenomenon: a total eclipse of the Sun visible between the contiguous borders of the United States of America (US).

To prepare for the total solar eclipse of 7 August 1869, the US Nautical Almanac Office (NAO), a government agency, invested time, staff, and substantial appropriations into physical astronomy measurements and the recording of the event photographically. Although no NAO employee had previous expertise, these efforts led the way for the adoption of astronomical photography at the US Naval Observatory, which would eventually absorb the NAO. In addition, an NAO associate would go on to lead the Harvard College Observatory, which would develop the most extensive US collection of photographic astronomical observations. The resulting photographic plate archives continue to be a resource for twenty-first century astronomers.

Keywords: U.S. Naval Observatory, Nautical Almanac Office, solar eclipses, 1869 solar eclipse, astronomical photography.

1 INTRODUCTION

Although today spectacular astronomical images are beamed to computer displays globally, the human eye was the only detector of starlight for millennia. The observer subjectively captured what he, or she, saw on clay, papyrus, parchment, or paper, in accordance with the writing technology of the day. However, in January 1839, Louis Jacques Mande Daguerre (1787–1851) announced his practical process for capturing and fixing an image on a copper plate for others to view ([Gernsheim, 1968](#); [Wickliff, 1998](#)).

Dominique François Arago (1786–1856), Director of the Paris Observatory, included mapping the surface of the Moon and comparisons of absolute stellar luminosities among the many scientific benefits expected from the new technology ([Ten, 2014](#); [Wickliff, 1998](#)). Indeed, John William Draper (1811–1882), a Professor of Chemistry at the University of the City of New York (now New York University) captured the first astronomical daguerreotypes: the Moon in 1840 and the solar spectrum in about 1845 ([Williams, 2014](#)). The superiority of daguerreotypes over human eyes and hands for recording scientific details was tempered by the difficulties in reproducing and distributing the images.

The wet collodion process developed by sculptor Frederick Scott Archer (1813–1857) in 1851 enabled multiple paper prints to be made from an original glass negative. This process also allowed for shorter exposure times and

could record fainter stars ([Wickliff, 1998](#); [Wood and Ward, 2022](#)). In 1857, William and George Bond (1789–1859 father, 1825–1865 son) and John Whipple (1822–1891) used this process to image Mizar and Alcor (3rd and 5th magnitude, respectively) at the Harvard College Observatory (HCO). Alcor is nearly 40 times fainter than Vega (1st magnitude), which they had photographed using Daguerre’s method seven years earlier ([Lamuniere, 2008](#); [Turner, 2014a](#); [2014b](#)). However, the process prohibited lengthy exposure times to capture faint stars because the photographer had to develop the plates while the collodion remained moist ([Gendler and GaBany, 2015](#)).

By 1880, commercially produced dry gelatin photographic plates were available based on the 1871 suggestions of Richard Maddox (1816–1902). This process addressed the deficiencies of the earlier photographic technologies, allowing plates to be prepared well in advance, to be exposed as long as necessary, and to be developed when convenient ([Anonymous, 1902](#); [Common 1887](#)). Henry Draper (1837–1882), son of John Draper, took the first known successful image of a nebula in 1880 when he photographed the Orion Nebula. An amateur, he is best known for his work in photographic spectroscopy ([Gendler and GaBany 2015](#); [Gibson, 2014](#)).

Astronomers adopted photographic plates as their recorder of choice for most of the twentieth century. Today, more than 4 million of these pieces of glass store unique sky views that are

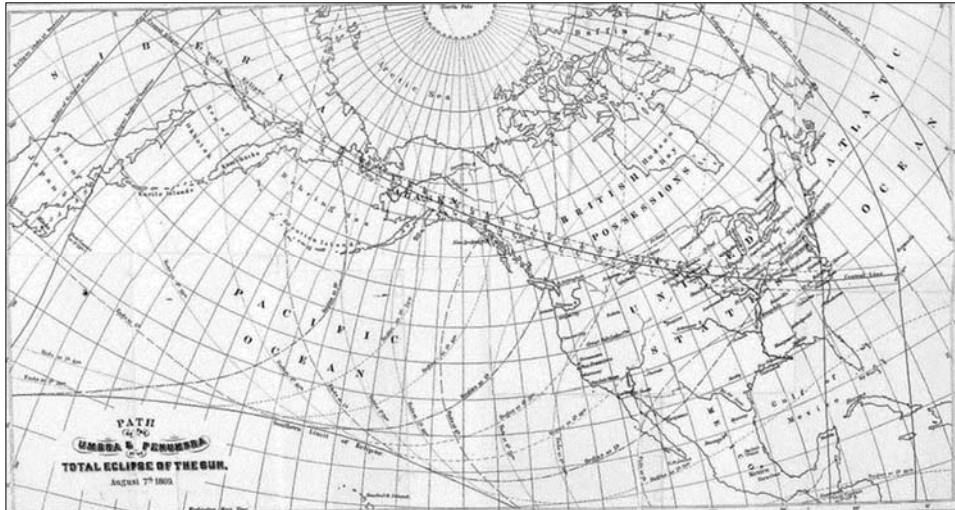


Figure 1: Path of the umbra and penumbra of the total solar eclipse of 7 August 1869 (after [NAO, 1869b](#)).



Figure 2: Locations in the US where successful observations of the eclipse were made. Key: 2 = Sioux Falls (Fort Dakota); 3 = Jefferson; 4 = Des Moines; 5 = Ottumwa; 6 = Mount Pleasant; 7 = Burlington; 8 = Springfield; 9 = Vincennes; 11 = Jefferson; 12 = Shelbyville; 13 = Nicholasville; 18 = Wilmington (map: Wayne Orchiston).

revealing how stellar objects move and evolve over decades ([Pevtsov et al., 2019](#); [Whitten et al., 2024](#)). While time-domain astronomy is on the cutting edge of twenty-first century science, the technology of detecting and recording starlight moved from photographic plates to charge-coupled devices (CCDs) starting with a 1974 image of the Moon ([Gendler and GaBany, 2015](#)).

The transition from visual to photographic observations occurred gradually over the last quarter of the nineteenth century and beginning of the twentieth century, alongside the transition from traditional astronomy based on positional and kinetic measurements (astrometry) and

morphological observations to the new physical astronomy that incorporated techniques from physics and chemistry laboratories. However, photography was agnostic in the late nineteenth century debate over ‘real’ astronomy. Despite its accompanying chemical laboratory, or dark room, photography could, and did, record astrometric, morphological, photometric, and physical astronomy observations.

In the US, the NAO showcased the potential of photographic techniques during the 7 August 1869 total solar eclipse, which swept diagonally across North America; [Figures 1 and 2](#) illustrate the path. This Government agency, in particular, invested significant resources—

time, personnel, and funds—in the production of photographic records, as well as physical astronomy measurements. They explored these technologies at three Iowa locations despite NAO staff having neither previous expertise nor interest in such processes.

2 BACKGROUND

In the second half of the nineteenth century, the leading US astronomers were primarily employed by the Government. The gatekeepers of US astronomy were those working for government-sponsored entities. Of the forty-nine charter members of the National Academy of Sciences, six were government astronomers.

For example, the US Congress assigned the publication of astronomical data relevant to navigation to the NAO, a mission it retains today. The *American Ephemeris and Nautical Almanac* of 1869 is now *The Nautical Almanac*, a joint US and United Kingdom publication. Figures 3 and 4 show *The Nautical Almanac*, then and now. The US Congress tasked the USNO, shown in Figure 5, with establishing precise time, a navigational essential for which it remains responsible. Until about 1894, the NAO and USNO were separate institutions; USNO would not fully ingest the NAO for about a decade (Dick, 2007). Today, the NAO is a Division within the USNO Celestial Reference Frame Department. Because both institutions required personnel proficient in astrometry, staff shifted between the two (*ibid.*). Work at NAO was primarily computational while USNO hosted observational programs.

To determine their longitude, celestial navigators, like NAO Superintendent John Coffin (1815–1890, see Figure 6), observed the altitudes, or heights above the horizon, of select bodies at a given time (Coffin, 1968; Comstock, 1913). By comparing the predicted time and altitude of a body for a standard longitude with his, or her, observation, a navigator knows how far east or west she, or he, is from the standard meridian. Navigators usually observe fifty-eight select stars, the Sun, the Moon, and four of the naked-eye planets. As an extreme case, the difference in eclipse contact times observed locally and those printed in an almanac translates into the observer's longitude. Therefore, historically, astrometrists timed eclipses to hone their predictions of future eclipse circumstances and to improve their models of solar and lunar motions. Previously, the observers of the 28 July 1851 solar eclipse tested NAO models while the NAO sent an expedition to observe the 18 July 1860 total solar eclipse and test their theories (Dick, 2007). NAO and USNO astronomers, therefore, planned to observe the

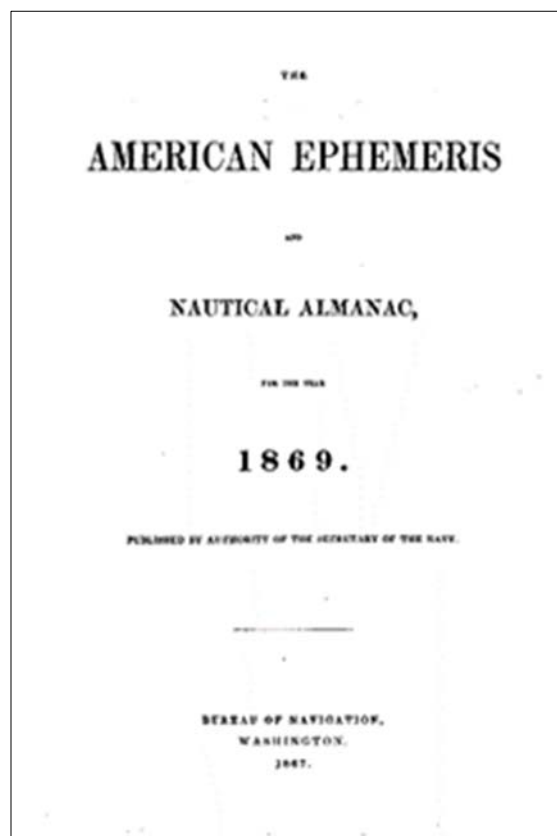


Figure 3: Title page from *The American Ephemeris and Nautical Almanac for the Year 1869* (after NAO, 1969a).

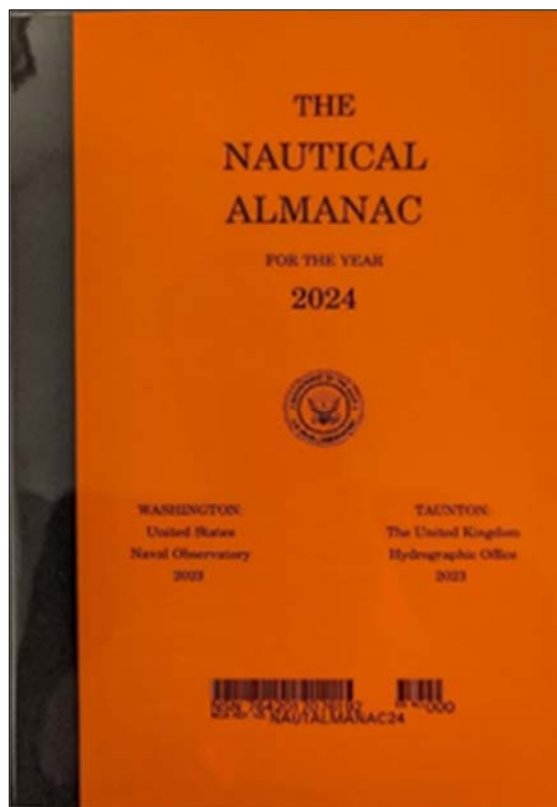


Figure 4: Cover of *The Nautical Almanac for the Year 2024* (after USNO and HMNAO, 2024).



Figure 5: The U.S. Naval Observatory, ca.1879 (courtesy USNO, <https://www.history.navy.mil/browse-by-topic/exploration-and-innovation/first-us-naval-observatory.html>).

total solar eclipse on 7 August 1869.

By 1869, land surveyors were replacing celestial observations with telegraph signals. Once a line was strung, a surveyor could compare his local clock with the almost instantaneous time signal from a known longitude, such as those generated at USNO, or another observatory, to determine how far east or west



Figure 6: John H.C. Coffin (after [Comstock, 1913](#)).

he was from the known longitude. Telegraph lines carried signals around the clock, even on rainy days and cloudy nights. Therefore, the United States Coast Survey (USCS) also undertook eclipse expeditions. This third, non-astronomical Government agency determined the exact *location* of every observing site (see [Coffin 1877a](#)). Frequently, a USCS observer would survey a site and make his own eclipse observations.

Beyond their traditional navigational role, NAO and USNO had the potential to function as a *de facto* national observatory. John Quincy Adams (1767–1848) called for such an institution in his 1825 Presidential Address but settled for the USNO in 1846. Meanwhile, Matthew Fontaine Maury (1806–1873), the first USNO Superintendent, claimed the honor of ‘national observatory’ for his institution in 1846 ([Dick, 1991; 2007; Maury, 1846](#)). In this expansive vision, their scientific accomplishments would compete with the great state observatories of Europe, contributing to national prestige. As Europe increasingly embraced what was known as physical astronomy, achieving this goal required applying laboratory techniques to understanding celestial objects as well as producing highly accurate astrometry.

As the 1869 total solar eclipse approached, US Government-funded astronomers anticipated that their European counterparts would assess their scientific performance and the tools they applied. In addition, as documented by [Cottam and Orchiston \(2015\)](#), the US public was increasingly consuming popular accounts

of astronomical events, especially those visible from within the national borders.

Despite a patriotic appeal, the idea of a national observatory was politically controversial. Congress had repeatedly rejected Adams' proposals; and the USNO was supposed to be a small practical institution (Dick 1991; 2007). However, Government astronomers had supplied the navigation aids and chronometer calibrations necessary for maritime success throughout the US Civil War (Dick, 2007). Therefore, support for expanding the scientific mission was possible during what historian Steven Dick (2007: 160) calls the "golden era" for the NAO and the USNO. As long as the NAO reliably published its almanacs, Congress would allow some 'mission creep.' In its 1869 appropriations, Congress would go so far as to expect the NAO to do more than just time the passage of the Moon across the Sun's face (Coffin, 1877a).

3 THE NAO ECLIPSE EXPEDITION OF 1869

The NAO mathematicians were poorly equipped to undertake scientific observations during a total solar eclipse. With a primarily computational mission, they had no telescopes. Nevertheless, Coffin asserted an important eclipse role for his agency.

While the USNO used its own personnel, the NAO sought assistance from outsiders, primarily academics. The NAO accomplishments, and misadventures, associated with the 1869 expedition were because of these loosely affiliated personnel, who received Government logistical and financial support.

After obtaining endorsements from the American Academy of Arts and Scientists, the American Philosophic Society, and the Franklin Institute, Coffin (1877a) asked the US House of Representatives to fund the NAO expeditions. Congress appropriated \$5,000 (over \$100,000 today) "For observation of the eclipse of the Sun in August, 1869, under the direction of the Superintendent of the Nautical Almanac" (40th Congress, 1869: 6). The appropriation covered

... defraying expenses of observers, of moving instruments of sufficient power to the line of central eclipse, and of preparing for abundant photographic records and spectroscopic observations (Coffin, 1877a: 3).

Thus, the first Government funding for an astronomical expedition specified adding photographic observations to the traditional visual timing procedures as well as the collection of physical astronomy data.

Because maximum eclipse occurred in the inaccessible Yukon Range, Burlington (Iowa) was the main NAO expedition site (Coffin, 1877a). Burlington was very near the eclipse centerline with an anticipated 2 minutes, 53 seconds of totality (USNO, 2012) and likely to be clear on eclipse day (Coffin, 1877a).

Coffin solved the NAO instrumentation deficit by borrowing. Philadelphia Central High School, Pennsylvania College (now Gettysburg College) and the University of Pennsylvania all loaned their telescopes (Coffin, 1877a). The 1869 solar-eclipse photographers got the three telescopes: two 6.4-inch (16.3-cm) Merz & Mahler refractors and a 4-inch (10-cm) Dollond instrument. All three were equatorially mounted, but the Dollond did not have a clock drive (Morton, 1869).

The USNO contributed chronometers and other equipment to the NAO expedition. In addition, Western Union allowed NAO free telegraph services (Coffin, 1877a).

The railroads—Pennsylvania Central; Chicago, Burlington, and Quincy (Great Burlington Route); and Burlington and Missouri—were also generous to the NAO with in-kind contributions of an estimated \$1,500 (about \$35,000 today). The companies provided free travel along their lines. Pennsylvania Central Railroad also outfitted a special train car for the principal participants and most of their assistants by removing seats to accommodate instruments. In addition, railroad employees actively facilitated their travel (Coffin, 1877a; Morton, 1877).

Despite the devastation of the recent conflict, Coffin raised sufficient resources to equip two NAO stations besides Burlington; these were also in Iowa. While August in Iowa is generally fair, the weather is unpredictable enough that dispersed stations were a practical precaution against clouds at any one location. The photography-detailed telescopes were also scattered among the three observing stations to bedevil clouds (Morton, 1869). However, "... the weather on the eventful day of the eclipse was, at all our stations, perfect ..." (Morton, 1869: 208).

At each station, an NAO assistant coupled instruments and telescopes, although an NAO scientist might observe the procedures and learn the techniques. Traditional visual contact timing remained the primary responsibility of the NAO astrometrists. Table 1

lists the significant events in 1869.

To meet the Congressional photography requirement, Henry Morton (1836–1902; Figure 7), a University of Pennsylvania Chemistry Professor who was also Secretary of the Franklin

Table 1: Solar eclipse circumstances for Burlington, Iowa on 7–8 August 1869 (after [USNO, 2012](#)).

Contact	Time (UT1)	Description
First	22:00:45.6	leading lunar limb reached the solar limb initiating partial eclipse
Second	23:02:08.8	trailing lunar limb reached the solar limb beginning totality
Third	23:05:01.4	leading lunar limb reached opposite solar limb ending totality
Fourth	00:01:07.2	trailing lunar limb moved away from the solar limb ending partial eclipse

Institute, recruited Philadelphia camera enthusiasts to accompany the NAO astronomers ([Morton, 1877](#); [Sellers, 1894](#)). Participants had to be

... those whose position or engagements would allow them to volunteer without other compensation than the moral contingent [up]on success ... ([Morton, 1877: 116](#)).

While a visual observer could work alone, photographic teams using the modern wet collodion process required several—between five and seven—people to ensure pictures were recorded and developed expeditiously ([Morton, 1869](#)).

Photographic assistants prepared wet collodion plates by spreading glass sheets with a potassium iodide solution and then dunking them in into a bath of silver nitrate. The chemicals reacted producing the silver iodide salt that would react to light. Once the photographer had exposed the photographic plate, the team had to develop it in an on-site darkroom. To be successful, these actions had to be completed in under 15 minutes ([Gendler and GaBany, 2015](#)). Earlier, British physicist William Crookes (1832–1919) had recommended using multiple photographic technologies for maximum output ([Cottam and Orchiston, 2015](#)).

3.1 Burlington Station

Professor Charles Young (1834–1908; [Figure 8](#)) of Dartmouth College accompanied Coffin to Burlington to observe the Sun spectroscopically and to ascertain its nature. He was as expert a spectroscopist as was available and his presence met the Congressional request for spectroscopic observations. Despite his application of physics to studying the Sun, he was a visual observer who would be credited with detecting a new green coronal emission line due to highly ionized iron ([Habashi, 2014](#); [Young, 1877](#)). In fact, Madras Observatory Director Norman Pogson (1829–1891) previously saw this line during the Indian eclipse of 18 August 1868 ([Nath, 2013](#)), but his discovery was not publicized at the time ([Nath and Orchiston, 2021](#)).

Alfred Mayer (1836–1897; [Figure 9](#)), a Professor of Physics and Astronomy at Lehigh University, oversaw photography *in situ* at Burlington ([Mayer, 1869](#); [Stevens, 1897](#)). Today, a bronze plaque in South Hill Park marks the former location of their stone pier with professional astronomers and amateur photographers arranged in the same area ([Coffin, 1877b](#)). During the eclipse, Mayer and his assistant photographers worked inside a makeshift, planked observatory alongside Young and his spectroscope ([Morton, 1869](#)).

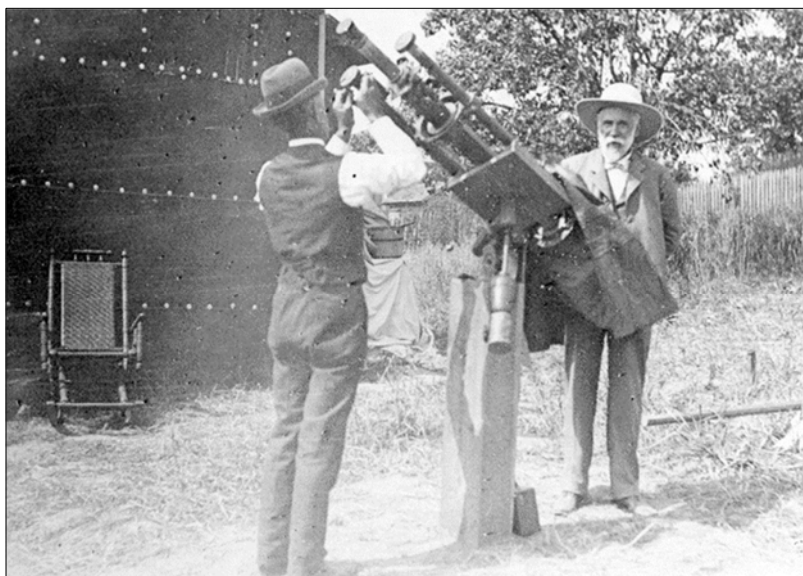
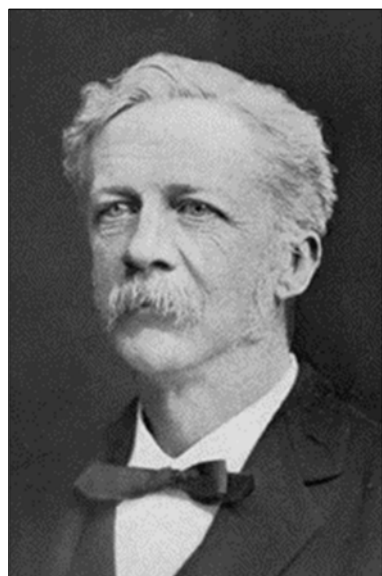


Figure 7 (left): Henry Morton, first President of the Stevens Institute of Technology (courtesy: Stevens Institute of Technology; [https://en.wikipedia.org/wiki/Henry_Morton_\(scientist\)#/media/File:HenryMortonPortrait.jpg](https://en.wikipedia.org/wiki/Henry_Morton_(scientist)#/media/File:HenryMortonPortrait.jpg)).

Figure 8 (right): Charles Young (right) and an unidentified assistant with a spectroscope in ca. 1897 (courtesy: AIP Emilio Segrè Visual Archives, Mary Russell Edmondson Collection).

While the photography teams were at work, Coffin and his professional NAO astronomers observed the eclipse visually in the traditional manner. They positioned themselves outside and about six meters west of the temporary structure. Separating the groups ensured that each could accomplish their assignments without being distracted by the other (Coffin, 1877b).

Mayer had carefully scripted the photographic activity for the Burlington photography team in advance to ensure smooth eclipse day operations. He wanted

- one picture every 4 to 5 minutes during the partial phases of the eclipse.
- five rapid pictures starting just before the computed time of first contact.
- one picture just before and one just after second contact.
- one picture just before and one just after third contact.
- five rapid pictures starting around fourth contact.
- During totality? As many as possible! (Mayer, 1869)

His plan should have produced the abundant photographic observations required by Congress.

During the partial phases of the eclipse, a diaphragm reduced the 6.4-inch telescope aperture to 2 inches (5 cm), decreasing the light entering the camera. During the initial partial phase, exposures mostly followed Mayer's plan. For instance, when Young announced that the lunar limb had nearly covered half of a large sunspot, Mayer snapped the shutter, producing an image with the sunspot umbra bisected (*ibid.*).

Approximately 5 minutes before second contact, an assistant photographer removed the diaphragm from the telescope. With the full aperture unblocked, all available sunlight could reach the camera during the total phase (*ibid.*).

Mayer took the last photograph of the partial phase with the unblocked aperture just seven seconds before second contact. During the first 116 seconds of totality, Mayer (*ibid.*) took five more photographs.

With 50 seconds remaining before third contact, Mayer was anxious to make another set of exposures, but he had no prepared glass at hand. "plate! plate!!" (Mayer, 1869: 259) he cried to no avail. Despite his desire to expose and expose again, he was a mere visual observer for the rest of totality (Mayer, 1869).

The ambitious observing cadence and the short window of totality had inundated the sta-

tion's darkroom: six plates in 2 minutes and 3 seconds.

Photography resumed over 29 seconds after third contact. Returning to the scheduled and manageable four-minute cadence, photographers captured another six images during the second partial phase (*ibid.*).

Finally, Mayer used up the available plates with four more images of the uneclipsed Sun (*ibid.*).

Consisting of Mayer and five assistants, his team was still overwhelmed by the need to adjust the telescope, reset the shutter, expose the plate, and record the time ... simultaneously. At the beginning and ending of each exposure, the photographer should have triggered an electric circuit that caused a remote pin to mark a paper tape. Measuring the distances between the marks on this chronographic

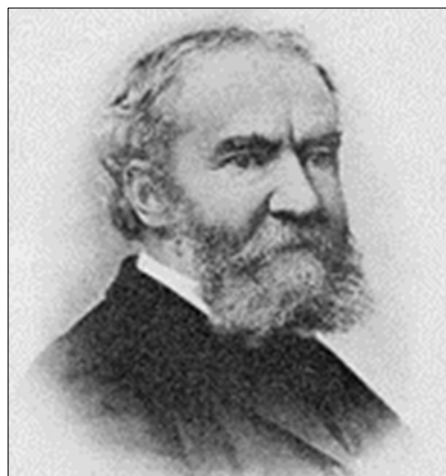


Figure 9: Portrait of Alfred Mayer (courtesy: AIP Emilio Segrè Visual Archives, Physics Today Collection).

record would reveal the exposure time. When reviewed, the tapes disclosed that team members triggered the signal when they could amid their myriad duties rather than with the desired precision (*ibid.*).

3.2 Mount Pleasant Station

The second NAO expedition station was in Mount Pleasant, Iowa. The NAO-contracted staff, shown in Figure 10, also had a strong physical astronomy component as well as their own ancillary troupe from the Philadelphia Photographic 'Corps'.

Morton chose Mount Pleasant for his own team during the eclipse (Morton, 1877). They established a makeshift 'bservatory' at the Henry County Agricultural Society fairgrounds to house the small Dollond telescope donated by the University of Pennsylvania that Morton



Figure 10 (left): Members of the NAO expedition to Mount Pleasant. In the front row starting at left are Edward Pickering, James Watson (in chair), John Van Vleck (in chair) and George Merriman. Likewise, in the back are Donald McIntyre and William Johnston (Van Vleck's Assistant). The man in the doorway is unidentified (courtesy Detroit Observatory).

Figure 11 (below): E.C. Pickering (<https://discover.hubpages.com/education/Edward-Charles-Pickering-19th-Century-Astronomer>).



had selected for his own use (Coffin, 1877a; Morton, 1869; Watson, 1877).

Edward Pickering (1846–1919; Figure 11), a Massachusetts Institute of Technology Professor, also accompanied the NAO personnel to Mount Pleasant. In 1869, he was a physicist, neither a traditional nor a physical astronomer, with experience in the technique of laboratory spectroscopy (Pickering, 1868; Smith, 2014).

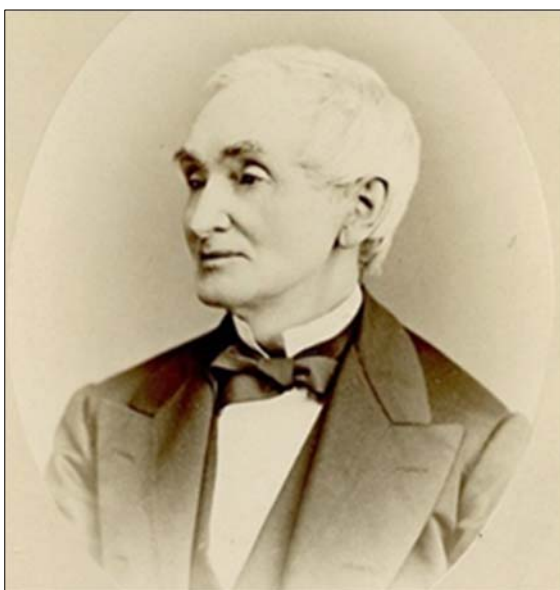


Figure 12: Stephen Alexander (courtesy: Princeton University Archives, Department of Special Collections).

Although not a photographer either, Pickering suggested pointing a "... common portrait camera ..." (Pickering 1877b: 156) with the biggest possible lens at the Sun for the duration of totality. In contrast to Mayer's detailed plan, the Hoover brothers, two local photographers, bet all or nothing on a single lengthy exposure (Pickering, 1877b). No one had asked them to produce copious photographic observations.

Pickering, himself, eschewed simplicity and photography. He juggled an impressive-sounding suite of instruments from the window of his room in the Brazelton House hotel (Pickering, 1877a). However, none of his experiments produced new science.

3.3 Ottumwa Station

Prior to 1869, Professor Stephen Alexander (1806–1883; Figure 12) of Princeton University had amassed a phenomenal record of solar eclipse observations from personal experience and the literature. However, his anecdotal research methodology that employed little analysis was out-of-date in a world ready for physical astronomy (Young, 1884). Consequently, he led the NAO expedition to Ottumwa, Iowa, a secondary station rather than the flagship station in Burlington (Alexander, 1877). His chief photographer was Charles Himes (1838–1918; Figure 13), a Professor of Natural Science at Dickinson College, who had published in the

American Journal of Photography and was the author of *Leaf Prints; or Glimpses at Photography* (Himes, 1868; Vodra, 1997).

The last group of NAO civil servants and Philadelphia photographic volunteers established their station in a manner similar to the other two. They had a standardized, temporary observatory designed by Coffin to house their telescope. Likewise, each member of the photography team had a duty to perform comparable to those on other teams. However, Ottumwa had no local photographers to contribute to the effort (Himes, 1869).

The first challenge to the Ottumwa party was damage to the telescope clock drive that occurred on their way to Iowa. They successfully disassembled, repaired, and reassembled it onsite. But,

The trouble and anxiety which this cause of delay occasioned, was, however, no small trial of fortitude to the Ottumwa party. (Morton, 1869: 208).

The second challenge to the Ottumwa party was the misplacing of their chronometer; they had inadvertently left it in Burlington. Fortunately, Alexander had packed a spare. As at Burlington, the Ottumwa photographic party was too frantic during totality to record exposure start times promptly. Therefore, they extrapolated photographic times after the event (Himes, 1869).

Ultimately, the relatively inexperienced Ottumwa party exposed only three plates during totality. Of the other thirty-six Ottumwa photographs, four were unusable because of poor placement of the Sun or other technical issues (*ibid.*).

Not a photographer, Alexander (1877) tried to measure the heat of the corona during totality using a thermo-electric pile. Although he had previously measured the relative temperature of sunspots (Henry and Alexander, 1845), his first-ever application of an electronic instrument during a total solar eclipse failed (Alexander, 1877).

3.4 Photographic Output

The NAO photographers were not the first to photograph a solar eclipse. European astronomers made daguerreotypes during the 1842 and 1851 events. Warren De la Rue (1815–1859), who served twice as President of the Chemical Society and once as President of the Royal Astronomical Society, obtained at least 40 photographs of the 18 July 1860 total solar eclipse from Spain using the wet collodion process. Pietro Angelo Secchi (1818–1878), a

Jesuit priest and visual stellar spectroscopist, also photographed that event (Cenadelli, 2014; Hingley, 2001).

Reviewing the descriptions of the 1860 photography was no preparation for the reality of experiencing a total solar eclipse. During totality, photographic conditions change rapidly with solar conditions. At every station, the NAO photographers avoided short, potentially insufficient, exposures. However, with hindsight, they surmised that one- or two-second exposures might have been sufficient to capture the larger, bright prominences. Such short exposures might also have produced better details for these



Figure 13: Charles Himes (courtesy: Dickinson College Archives and Special Collections; <https://archives.dickinson.edu/people/charles-francis-himes-1838-1918>).

these solar features. Morton's (1869) ruminations would help future solar eclipse photographers but could not undo the inadvertently over-exposed images from this event.

Mayer's photographs at Burlington station reproduced the solar prominences well, but failed to capture the elusive corona, which all the photographers sought. Inflating their success, he claimed that

Our work was finished, and ... was of the past, but its history we had faithfully recorded in forty-one perfect photographs.

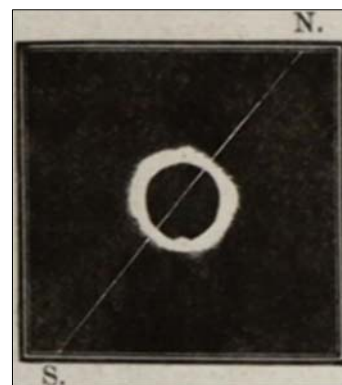
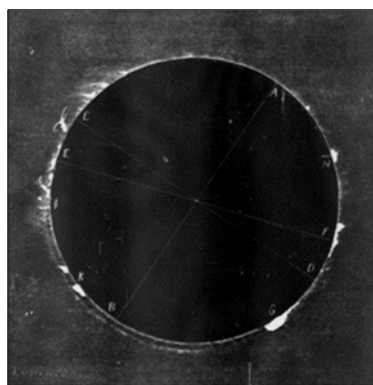
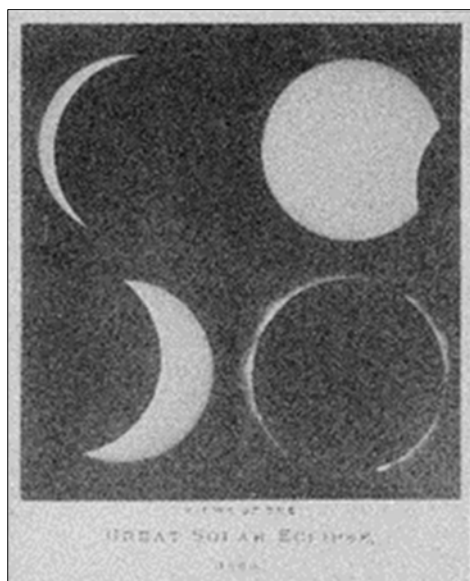


Figure 14: Views of the 1869 total solar eclipse (after *The Philadelphia Photographer*, Volume 6: Frontispiece).

Figure 15: View of the eclipsed Sun captured by Morton's party (after Lockyer, 1869).

Figure 16: A commercial photographer's photograph of totality, taken in 1869 at Mount Pleasant (courtesy: USNO).

Such good success as attended our efforts speaks for the entire devotion of each one to his allotted duties. Without this devotion on the part of each and all we would have failed, and the harmony and efficiency which pervaded our corps need no other witness. (Mayer, 1869: 260).

Like the Burlington photographers, the Mount Pleasant team was challenged to refrain from over-exposing the prominences. In doing so, they too failed to capture the details of the more subtle and much fainter corona. Figures 14 and 15 show some of the photographs they did capture. An exposure of

... five seconds was more than sufficient to secure all the details of the protuberances [prominences], although it gave no decided indication of the corona. (Morton, 1877: 123).

Following Pickering's advice, the gamble taken by local Mount Pleasant photographers produced the detailed image in Figure 16 that displays an inner and an outer corona, two visually distinct regions. Simply executed, this picture rivaled everything produced by the Philadelphia Photographic 'Corp' (Morton, 1869; Pickering, 1877b).

Despite the paucity of photographs taken at the Ottumwa station, Himes captured an important phenomenon during second contact. One picture, exposed at the very last instant before totality, recorded

... the curious phenomenon known as Baily's beads, being simply the last glimpse of the sun's edge cut by the peaks of lunar mountains into irregular spots (Morton, 1877: 123).

It was the first photograph of the phenomenon previously described by Edmond Halley (1656–1742) in 1714 and Francis Baily (1774–1844) in 1836 (Luminet, 2014; Yeomans, 2014). Figure 17 shows the partial phase seen from Ottumwa.

In addition to the NAO-affiliated photographers, a photographer joined the USNO astronomers at their Des Moines, Iowa, site while at least five other stations hosted camera men. Although the Bonds did not live to see the eclipse of 1869, Whipple accompanied the USCS to Shelbyville, Kentucky, where he captured the image in Figure 18, which was the first photograph of the diamond ring effect. When only one or two Baily's beads remain, the sunlight glimpsed through a lunar valley appears to resemble a bright, gleaming diamond. The USCS also captured 100 more photographs near Springfield, Illinois. In addition, the Cincinnati Observatory team captured a series of photographs of the partial phases from Fort Dakota in the Dakota Territory (Sioux Falls, South Dakota). Furthermore, a Canadian party took photographs from Jefferson, Iowa (Cottam et al., 2011). The Davenport Academy of Sciences took advantage of their location as the eclipse crossed Iowa to obtain 24 exposures, 3 minutes apart, including Figure 19 (Davenport, 1869).

While the overall scientific return on the photographs taken during the 1869 solar eclipse was slight, they demonstrated the potential of astronomical photography, which would play a significant role in the coming transit of Venus expeditions in 1874 and 1882 (e.g., see Sheehan and Westfall, 2004).

4 DISCUSSION

The scholarly debate in the US regarding the



Figure 17 (left): A view of the partial phase of the solar eclipse on 7 August 1869 (courtesy: Dickinson College Archives and Special Collections).

Figure 18 (centre): The 'Diamond Ring', photographed by the USCS from Shelbyville, KY (courtesy: Harvard College Observatory).

Figure 19 (right): A view of the partial phase of the eclipse just after third contact, from Davenport, IA (courtesy: Putman Museum and Science Center).

merits of physical astronomy versus traditional astronomy would become heated throughout the remainder of the nineteenth century. Discipline-agnostic, photography would steadily replace the human eye as the detector of choice for recording physical astronomy data, morphological observations and positional measurements.

After taking part in the NAO expedition, Himes continued his research program in photography (Vodra, 1997). Although Young's career-long interest was visual astronomical spectroscopy, he photographed solar prominences during the 22 December 1870 eclipse (Habashi, 2014).

The USNO, which dabbled in photography during the 1869 eclipse and which eventually absorbed the NAO, increasingly invested in photographic observations despite the reservations of some staff (Cottam and Orchiston, 2015; Dick, 2007). With the assistance of Henry Draper, USNO personnel trained in Spring 1873 so that they could photograph the December transit of Venus successfully (Dick, 2007). Today, the majority of the USNO photographic plate collection is stored at the Astronomical Photographic Data Archive (APDA) hosted by the Pisgah Astronomical Research Institute (PARI; Barker et al., 2019; Cline et al., 2010; see Figure 20). The James M. Gillis Library at the USNO, shown in Figure 21, retains a small plate collection, including some of those taken in 1869. The Library is digitizing these and making them available through the Internet Archive (Black, 2021; Black and Bartlett, 2022; USNO, 2024).

Pickering, who in 1869 had but one paper published in his name (on laboratory spectroscopy) and was not a photographer, would

eventually reshape the HCO, shown in Figure 22, into a physical astronomy institution, creating a vast library of data recorded on over 600,000 photographic plates. Substantial funding for his efforts came from Mary 'Anna' Draper (1839–1914), widow of Henry Draper (Kohlstedt, 1999). Today, the Digital Access to a Sky Century @ Harvard (DASCH) program has digitized over 95% of the HCO collection and made them available online (Frommer, 2024; Williams and the DASCH Team, 2024). This photographic library continues to reveal new insights into the behavior of stars over decades (e.g. Li et al., 2022; Merc et al., 2022).

5 CONCLUDING REMARKS

In 1869, the NAO, which was the US agency most heavily committed to 1869 total solar eclipse endeavors, was one of the principal astronomical institutions of the Gilded Age. The NAO did so despite staff having no practical experience, history, nor publicly expressed interest in physical astronomy or photography. By the end of the century, the NAO would merge with the USNO, which had experimented to a lesser extent with this technology. Along with other astronomical institutions, the NAO and USNO moved from recording observations with paper and pencil to the chemical processes of photography 'overnight.' Or, more literally, over the course of 7 August 1869.

6 ACKNOWLEDGEMENTS

This research made use of the Science Explorer (SciX) and the SIMBAD database, operated at CDS, Strasbourg, France, and resources available through ADS and the Internet Archive.

I am grateful to Professor Thomas Hockey



Figure 20: The Pisgah Astronomical Research Institute. The building at the bottom far right houses the Astronomical Photographic Data Archives (https://www.tripadvisor.com/Attraction_Review-g49496-d5509787-Reviews-Pisgah_Astronomical_Research_Institute-Rosman_North_Carolina.html).



Figure 21: The Interior of the James Melville Gilliss Library (courtesy: USNO Library and Archives).

(University of Northern Iowa) for introducing me to the NAO expeditions of 1869 and for his contributions to the initial draft of this paper. I am also grateful to Professor Wayne Orchiston for pointing out that Pogson first detected the iron emission line in 1868.

Dr David DeVorkin also graciously encouraged the authoress when she was a graduate student, and was enthusiastic about the continuing potential of astronomical photographic plates. She was tracing the motion of Barnard's Star on McCormick Observatory plates to see if

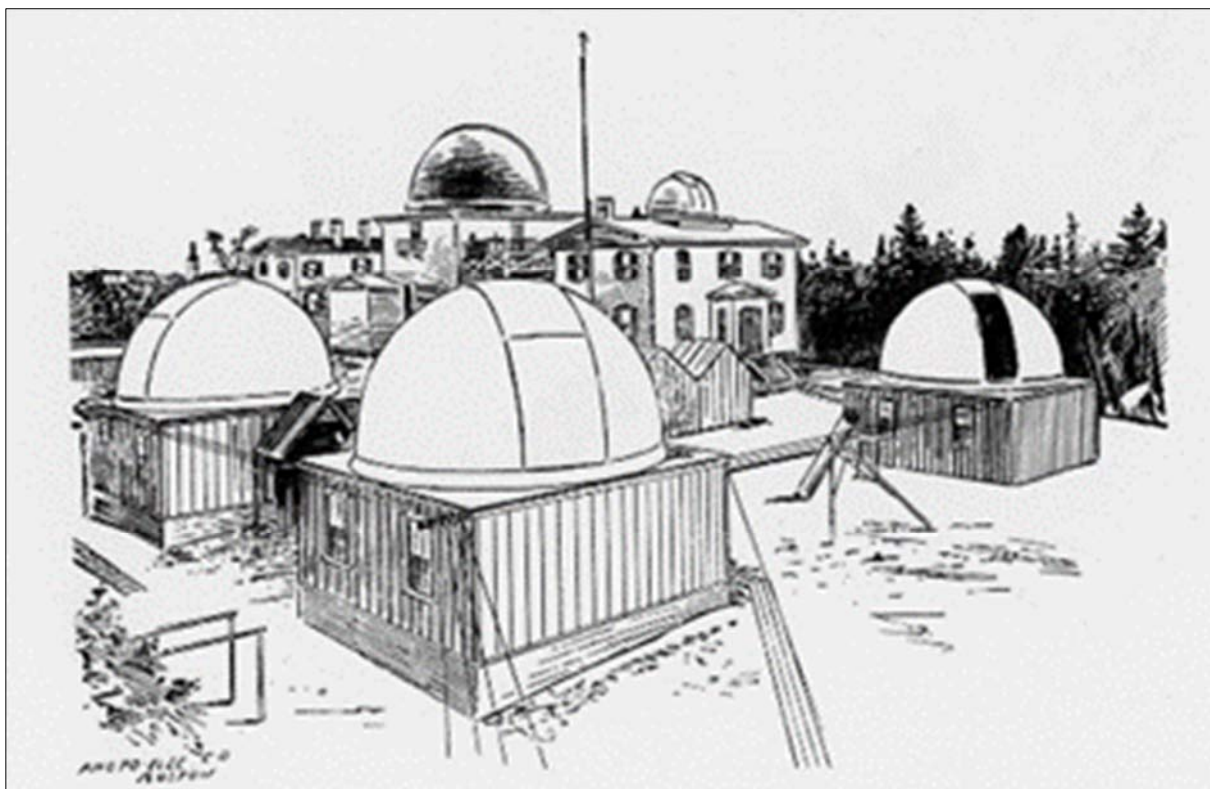


Figure 22: Harvard College Observatory, in about 1890 (courtesy: AIP, Emilio Segrè Visual Archives).

it hosted extra-solar planets. She is honored to have served with him on the American Astronomical Society's Working Group on the Preservation of Astronomical Heritage. She is grateful to DeVorkin for helping her understand that astronomy is deeply intertwined with its history and culture.

Finally, I wish to thank the following individuals and institutions for supplying some of the figures included in this paper: the American

Institute of Physics Emilio Segrè Visual Archives (Figures 8, 9 and 22); Detroit Observatory (Figure 10); Dickinson College Archives and Special Collections (Figures 13 and 17); Harvard College Observatory (Figure 18); Princeton University Archives (Figure 12); Professor Wayne Orchiston (Figure 2); Putnam Museum and Science Center (Figure 19); U.S. Naval Observatory Library and Archives (Figures 16 and 21).

7 REFERENCES

- 40th Congress, 1869. House Miscellaneous Document. *United States Congressional Serial*, 1385:6. Washington, DC, GPO.
- Alexander, S., 1877. Report of Prof. Stephen Alexander, Ottumwa, Iowa. In Coffin, 1877c, 101–110.
- Anonymous, 1902. The late Richard Leach Maddox, M.D. *The British Journal of Photography*, XLIX, 425–428.
- Baily, F., 1836. On a remarkable phenomenon that occurs in total and annular eclipses of the Sun. *Monthly Notices of the Royal Astronomical Society*, 4(2), 15–19 (<https://doi.org/10.1093/mnras/4.2.15>).
- Barker, T., DeLisle, T., Kagel, S., and Castelaz, M., 2019. Web Accessible Database of the Astronomical Photographic Data Archive. *Abstracts of the 233rd AAS Meeting (Seattle, WA)*, 567 (<https://sciploer.org/abs/2019AAS...23326204B/abstract>).
- Black (Aronson), M., 2021. Glass Plates and Log Books at the United States Naval Observatory. Presentation to the International Glass Plates Group (<https://osf.io/dtvxf>).
- Black, M., and Bartlett, J.L., 2022. USNO Glass Plates Update. Presentation to the International Glass Plates Group (<https://osf.io/chsnk>).
- Cenadelli, D., 2014. Secchi, (Pietro) Angelo. In Hockey, 1970–1972 (https://doi.org/10.1007/978-1-4419-9917-7_1253).
- Cline, J.D., Barker, T., and Castelaz, M., 2010. The Astronomical Photographic Data Archive. *Bulletin of the American Astronomical Society*, 42, 513 (<https://ui.adsabs.harvard.edu/abs/2010AAS...21546907C>).
- Coffin, J., 1868. *Navigation and Nautical Astronomy*. 4th Edition. New York, D. Van Nostrand.
- Coffin, J., 1877a. Report of Professor Coffin to the Secretary of the Navy. In Coffin, 1877c, 3–8.
- Coffin, J., 1877b. Report of Professor John H. C. Coffin, U. S. N., Burlington, Iowa. In Coffin, 1877c, 8–26.
- Coffin, J. (ed.), 1877c. *Reports of Observations of the Total Eclipse of the Sun, August 7, 1869, Made by Parties*

- Under the General Direction of Professor J. H. C. Coffin*, U. S. N. Washington, DC.
- Common, A.A., 1887. Astronomical photography. *The Nineteenth Century: A Monthly Review*, 120, 227–237.
- Comstock, G.C., 1913. *Biographical Memoir of John Huntington Crane Coffin 1815-1890*. National Academy of Sciences Biographical Memoirs, VIII, 1–7 (<http://nasonline.org/publications/biographical-memoirs/memoir-pdfs/coffin-john.pdf>).
- Cottam, S., and Orchiston, W., 2015. *Eclipses, Transits, and Comets of the Nineteenth Century: How America's Perception of the Skies Changed*. Cham (Switzerland), Springer (<https://doi.org/10.1007/978-3-319-08341-4>).
- Cottam, S., Pearson, J., Orchiston, W., and Stephenson, R., 2011. The total solar eclipses of 7 August 1869 and 29 July 1878 and the popularisation of astronomy in the USA as reflected in the *New York Times*" In Orchiston, W., Nakamura, T., and Strom, R.G. (eds.), *Highlighting the History of Astronomy in the Asia-Pacific Region*. New York, Springer. Pp. 339–375 (https://doi.org/10.1007/978-1-4419-8161-5_15).
- Davenport Academy of Natural Sciences. 1867. *Proceedings of the Davenport Academy of Natural Sciences. Volume 1 1867-1876*. Davenport, Academy of Natural Sciences (<https://www.biodiversitylibrary.org/item/88764>).
- Dick, S., 1991. John Quincy Adams, the Smithsonian bequest, and the origins of the U.S. Naval Observatory. *Journal for the History of Astronomy*, 22(1), 31–44.
- Dick, S., 2007. *Sky and Ocean Joined: The U.S. Naval Observatory 1830–2000*. Cambridge, Cambridge University Press (<https://archive.org/details/skyoceanjoinedus0000dick>).
- Frommer, A., 2024. A century of Sky, digitized. *Sky & Telescope*, August 2024.
- Gendler, R., and GaBany, R., 2015. *Breakthrough!: 100 Astronomical Images That Changed the World*. Cham (Switzerland), Springer (<https://doi.org/10.1007/978-3-319-20973-9>).
- Gernsheim, H., 1968. *L.J.M. Daguerre; the History of the Diorama and the Daguerreotype*. New York, Dover (<http://archive.org/details/ljmdaguerrehisto0000gern>).
- Gibson, S.J., 2014. Draper, Henry. In Hockey, 607–610 (https://doi.org/10.1007/978-1-4419-9917-7_380).
- Habashi, F., 2014. Young, Charles Augustus. In Hockey, 2400–2401 (https://doi.org/10.1007/978-1-4419-9917-7_1517).
- Halley, E., 1714. Observations of the late total eclipse of the Sun on the 22d of April last past, made before the Royal Society at their house in Crane Court in Fleet-Street, London. By Dr. Edmund Halley, Reg. Soc. Secr. with an account of what has been communicated from aboard concerning the same. *Philosophical Transactions of the Royal Society*, 29, 245–262 (<https://doi.org/10.1098/rstl.1714.0025>).
- Henry, J., and Alexander, S., 1845. A series of experiments relative to the spots on the Sun. *Proceedings of the American Philosophical Society*, 4(33), 173–176.
- Himes, C., 1868. *Leaf Prints; or Glimpses at Photography*. Philadelphia, Benerman & Wilson.
- Himes, C., 1869. Solar eclipse of August 7, 1869. *Journal of the Franklin Institute*, 88, 276–280.
- Hingley, P.D., 2001. The first photographic eclipse. *Astronomy and Geophysics*, 42, 1.18–1.23 (<https://articles.adsabs.harvard.edu/pdf/2001A%26G....42a..18H>).
- Hockey, T. et al. (eds.), 2014. *Biographical Encyclopedia of Astronomers. 2nd Edition*. New York, Springer.
- Kohlstedt, S.G., 1999. Draper, Mary Anna Palmer (1839-1914), philanthropist. In *American National Biography*. Oxford, Oxford University Press (<https://www.anb.org/view/10.1093/anb/9780198606697.001.0001/anb-9780198606697-e-1500910>).
- Lamuniere, M., 2008. John Adams Whipple (1822–1891): American Photographer and Inventor. In Hannavy, J. (ed.), *Encyclopedia of Nineteenth-Century Photography. Volume 2 (J-Z)*. New York, Routledge. Pp. 1494–1495.
- Li, L.-J., Qian, S.-B., and Zhu, L.-Y., 2022. Reanalysis of C-Type RR Lyrae variable BE Dor, Period modulations and mechanism. *Monthly Notices of the Royal Astronomical Society*, 510(4), 6050–6058 (<https://doi.org/10.1093/mnras/stab3808>).
- Lockyer, J.N., 1869. The recent total eclipse of the Sun. *Nature*, 14–15.
- Luminet, J.-P., 2014. Baily, Francis. In Hockey, 143–144 (https://doi.org/10.1007/978-1-4419-9917-7_99).
- Maury, M.F., 1846. *Astronomical Observations Made under the Direction of M.F. Maury, Lieut. U.S. Navy During the Year 1845 at the U.S. Naval Observatory, Washington. Volume I*. Washington, DC, J. & G.S. Gideon, Printers.
- Mayer, A., 1869. Solar eclipse of August 7, 1869. *Journal of the Franklin Institute*, 58, 249–275.
- Merc, J.R.G., Wolf, M., Velez, P., Bohlsen, T., and Barlow, B.N., 2022. Hen 3-860: new southern eclipsing symbiotic star observed in the outburst. *Monthly Notices of the Royal Astronomical Society*, 510(1), 1404–1412 (<https://doi.org/10.1093/mnras/stab3512>).
- Morton, H., 1869. Solar eclipse--August 7, 1869, the Philadelphia photographic expedition. *Journal of the Franklin Institute*, 88, 200–216.
- Morton, H., 1877. Reports of the Philadelphia photographic expedition. In Coffin, 1877c, 115–127.
- NAO, 1869a. *The American Ephemeris and Nautical Almanac, for the Year 1869*. Washington (D.C.), Bureau of Navigation.
- NAO, 1869b. *Total Eclipse of the Sun, August 7, 1869: Supplement to the American Ephemeris and Nautical Almanac for 1869*. Washington (D.C.), Bureau of Navigation.
- Nath, B.B., 2013. *The Story of Helium and the Birth of Astrophysics*. Cham (Switzerland), Springer.
- Nath, B.B., and Orchiston, W., 2021. Norman Robert Pogson and observations of the total solar eclipse of 1868 from Masulipatam. *Journal of Astronomical History and Heritage*, 24(3), 629–651.
- Pevtsov, A., Griffin, E., Grindlay, J., Kafka, S., Bartlett, J., Usoskin, I., plus 13 more authors, 2019. Historical astronomical data: urgent need for preservation, digitization enabling scientific exploration. *Bulletin of the American Astronomical Society*, 51(3), Astro2020 White Papers. Pp. 8. (<https://baas.aas.org/pub/2020n3i190/release/1>).

- Pickering, E., 1868. On the comparative efficiency of different forms of the spectroscope. *American Journal of Science*, s2-45(135), 301–305 (<https://doi.org/10.2475/ajs.s2-45.135.301>).
- Pickering, E., 1877a. Report of Prof. Edward C. Pickering, Mount Pleasant, Iowa. In Coffin, 1877c, 91–99.
- Pickering, E., 1877b. Photographing the Corona. In Coffin, 1877c, 156.
- Sellers, C., 1894. Henry Morton. *Cassier's Magazine*, 6, 337–344 (<https://hdl.handle.net/2027/nyp.33433090809413?urlappend=%3Bseq=1>).
- Sheehan, W., and Westfall, J., 2004. *The Transits of Venus*. Amherst, Prometheus Books.
- Smith, H.A., 2014. Pickering, Edward Charles. In Hockey, 1709–1712 (https://doi.org/10.1007/978-1-4419-9917-7_1090).
- Stevens, W.L. 1807. Alfred Marshall Mayer. *Science*, 6, 261–269 (<http://www.jstor.org/stable/1624620>).
- Ten, A.E., 2014. Arago, Dominique-François-Jean. In Hockey, 92–94 (https://doi.org/10.1007/978-1-4419-9917-7_63).
- Turner, S., 2014a. Bond, George Phillips. In Hockey, 264–266 (https://doi.org/10.1007/978-1-4419-9917-7_179).
- Turner, S., 2014b. Bond, William Cranch. In Hockey, 266–268 (https://doi.org/10.1007/978-1-4419-9917-7_180).
- USNO, 2012. *Multi-year Interactive Computer Almanac (MICA)*, Ver. 2.2.2. (software). Richmond, Willmann-Bell.
- USNO, 2024. United States Naval Observatory Library & Archives Collection, Internet Archive. (<https://archive.org/details/navobsy?tab=collection>).
- USNO and HNAO. 2024. *The Nautical Almanac for the Year 2024*. 2024th ed. Washington (D.C.), Government Printing Office.
- Vodra, S.L., 1997. Charles Francis Himes: portrait of a photographer. *Cumberland County History*, 14, 83–97 (<https://gardnerlibrary.org/sites/default/files/vol14n2.pdf>).
- Watson, J., 1877. Report of Prof. James C. Watson, Mount Pleasant, Iowa. In Coffin, 1877c, 77–89.
- Williams, P., and the DASCH Team, 2024. Completing the DASCH Project. *Bulletin of the American Astronomical Society*, 56(2) (<https://baas.aas.org/pub/2024n2i336p07/release/1>).
- Wilson, E., 1869. Photographing the eclipse. *The Philadelphia Photographer*, VI(69). (<https://link.gale.com/apps/doc/OTWSID869035068/NCCO?sid=bookmark-NCCO&xid=2a95283b>).
- Whitten, K., et al., 2024. Astronomy's photographic glass plates: demonstrating value through use cases. *Issues in Science and Technology Librarianship*, 106 (<https://doi.org/10.29173/istl2759>).
- Williams, T.R., 2014. Draper, John William. In Hockey, 610 (https://doi.org/10.1007/978-1-4419-9917-7_381).
- Wickliff, G.A., 1998. The Daguerreotype and the rhetoric of photographic technology. *Journal of Business and Technical Communication*, 12, 413–436.
- Wood, H.T., and Ward, J., 2022. Archer, Frederick Scott (1814–1857), inventor of the collodion process in photography. In *Oxford Dictionary of National Biography*. Oxford, UK, Oxford University Press (<https://doi.org/10.1093/ref:odnb/620>).
- Yeomans, D.K., 2014. Halley, Edmond. In Hockey, 891–894 (https://doi.org/10.1007/978-1-4419-9917-7_574).
- Young, C., 1877. Report of Professor C. A. Young. In Coffin, 1877c, 1–52.
- Young, C., 1884. Memoir: Stephen Alexander 1806–1883. *Biographical Memoirs of the National Academy of Sciences*, 249–259 (<http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/alexander-stephen.pdf>).

Dr. Jennifer Lynn Bartlett was born in Fairfax, Virginia (USA) in 1968. She has a BSc in Physics from Rensselaer Polytechnic Institute and MSc and PhD degrees in Astronomy from the University of Virginia. She is the Astrophysics Data System (ADS) Project Scientist for Astrophysics based at the Center for Astrophysics / Harvard & Smithsonian in Cambridge, Massachusetts. Formerly, she taught at the US Naval Academy and at Hampden-Sydney College. From 2010 to 2021, she was Chief of the U.S. Naval Observatory Software Products Division.

Jennifer's doctoral student investigated terrestrial atmospheric refraction. Her student also initiated the "This Month in Astronomical History" online column for this American Astronomical Society's Historic Astronomy Division (AAS). In addition, her two other graduate students, five undergraduate students, and two high school students have explored astrometry, astronomical history, and astronomy education topics.



A traditional astrometrist, Jennifer measured parallaxes to survey the Solar Neighborhood and promoted celestial navigation. However, she developed a love of the history of astronomy as a graduate student. For her dissertation, she analyzed photographic glass plates, and tried to corroborate the extrasolar planets previously described by Peter van de Kamp in the 1960s.

Along with Philip Nicholson of Cornell University, Jennifer is an Editor-in-Chief of the Third Edition of Springer's *Biographical Encyclopedia of Astronomers*. They are bringing the content into the twentieth century as well as adding astronomers missing from the Second Edition. She wrote *Solar System: Between Fire and Ice* (2021), a popular-level introduction to planetary science through a strong historical lens with Thomas Hockey from the University of Northern Iowa and Daniel Boice of Scientific Studies & Consulting.

The International Astronomical Union elected Jennifer to membership in 2012. She is currently an Organizing Committee member for Commission B2 (Data and Documentation) and Vice-Chair of the Commission B2 Working Group on the Preservation and Digitization of Photographic Plates. She also is a member of Commission C3 (History of Astronomy). For the AAS, she is Chair of the AAS Working Group on the Preservation of Astronomical Heritage, Vice-Chair of the Working Group on the Unified Astronomy Thesaurus, Assistant Director of the Astronomy

Genealogy Project, and an oral history interviewer. Additionally, she organizes the International Glass Plates Group.

In 2020, the AAS named Jennifer a Legacy Fellow for her contributions toward the Society's mission of enhancing and sharing humanity's scientific understanding of the Universe.