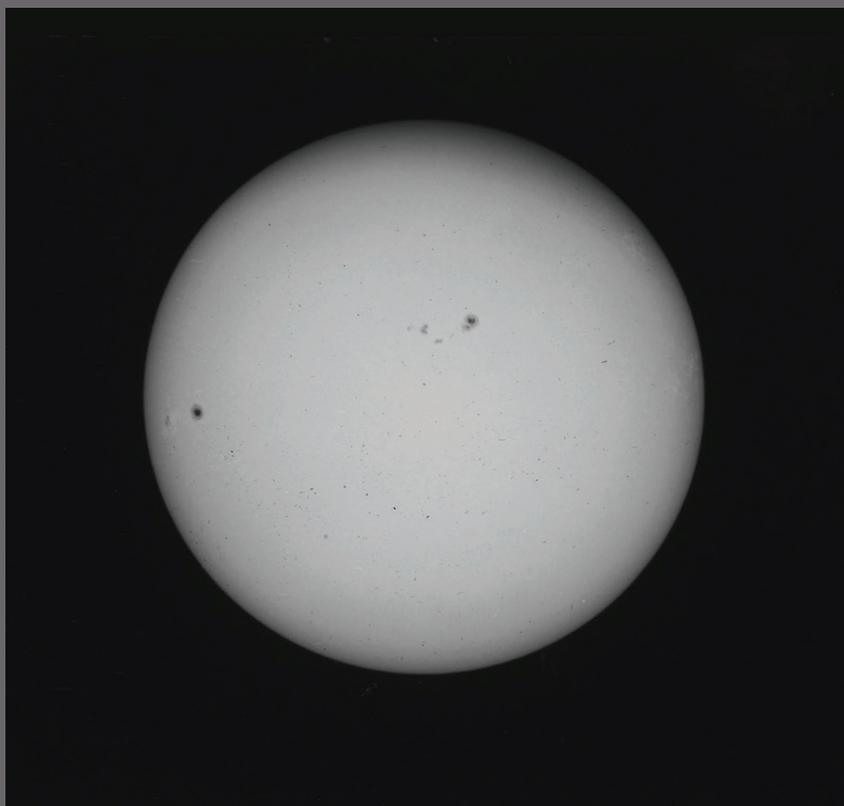
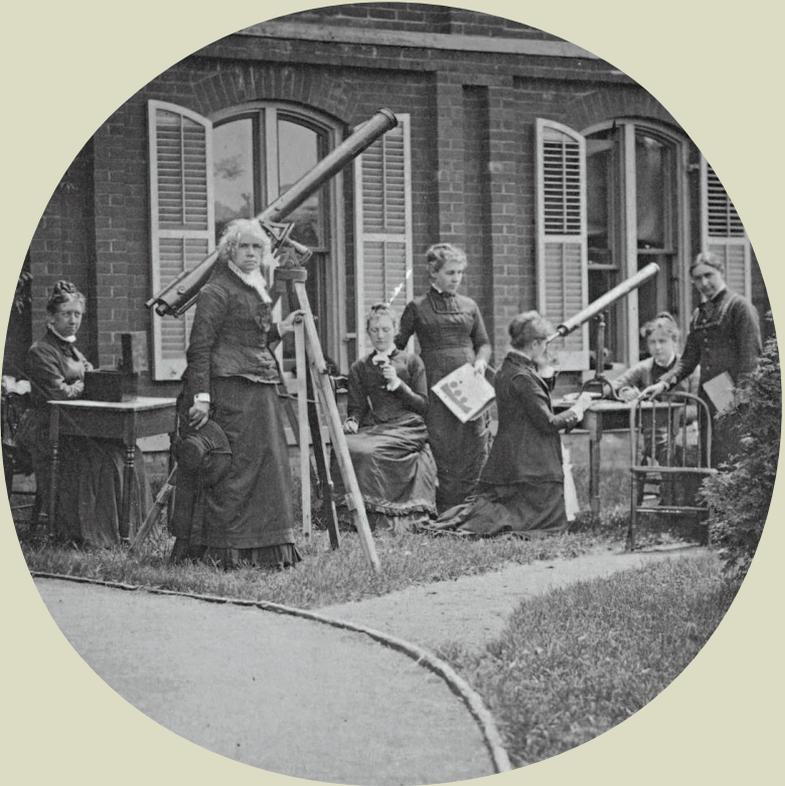


SEEING THE SUN

*Maria Mitchell's
Observations, 1868-1888*





Maria Mitchell and students outside the
Vassar College Observatory, 1878.

Front cover:

Print from original glass plate negative showing
sunspots observed by Mary W. Whitney and Hannah Mace
on the 8th of June, 1885.

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At the
Frederick Ferris Thompson Memorial Library,
Vassar College
2016

Notes on the Science

What are Sunspots?

The surface of the Sun (called the photosphere) has a temperature of 6000K (about 10,000 degrees F). The outer layers are convective, with rising and falling gas just as in the convective motions of the Earth's atmosphere. As the gas from lower levels rises, it expands and cools. But the Sun has a magnetic field, which at the start of a solar cycle is a dipole (like a bar magnet). Since the Sun is a fluid, gas at the equator rotates faster than gas at the poles, which tangles the magnetic fields. A sunspot occurs at a place where the field has buckled, so convection is impeded. The cool gas trapped at the surface is about 2000K cooler than the rest of the photosphere, so appears black by comparison.

Why study a solar eclipse?

When the Moon passes in front of the Sun, it temporarily blocks the Sun because by chance the Moon's apparent size is about the same as the Sun's apparent size (the Moon is of course much smaller than the Sun but proportionately closer to the Earth). The solar corona, the 1,000,000K gas that extends above the photosphere, is so low density that it is normally not visible. During an eclipse, its intricate structure can be studied because the Moon blocks the bright light from the photosphere.

Why study a Venus transit?

Venus is closer to the Sun than the Earth. A transit is when Venus crosses its front of the Sun. Note that Venus is about 1/100th the size of the Sun, so appears as a small black dot. Venus transits were historically interesting because they were used to calculate the Earth's distance from the Sun: if the transit of Venus were viewed from two different places on Earth, then timing of exactly when the transit occurred would allow the orbit to be calculated. The transits of 1874 and 1882 that Maria Mitchell and her students observed were the first ones to be recorded on photographs.

Why Study a Mercury Transit?

Mercury transits can also be used to measure the distance between the Earth and the Sun. Another use during Maria Mitchell's time was to determine the longitude of the observer through timing of the transit. Latitudes were easy to determine from measurements with sextants of star elevations as a function of time, but longitudes were more difficult to determine. Maria Mitchell, having grown up in the seafaring Nantucket community, was well versed in determining latitudes for navigational purposes. Even as a young girl, she helped her father by timing solar eclipses to determine their longitude. Timing the transits of Venus and Mercury serve the same purpose. Maria's measurements were used as input for the American Ephemeris and Nautical Almanac.

Transits of Venus and Mercury are relatively rare; Mercury transits the Sun about 13-14 times per century, whereas more distant Venus transits twice in an 8 year period separated by a gap of 121.5 or 105.5 years. There were Venus transits in June 2004 and 2012; the previous ones were in 1874 and 1882, when Maria observed them. The next won't occur till 2117 and 2125.

The next Mercury transits will be in May 2016 and Nov. 2019.

Essay by Debra Meloy Elmegreen

Professor of Astronomy on the
Maria Mitchell Chair

Maria Mitchell, America's first female astronomer, was also a pioneer of astrophotography and the first scientist to photograph the Sun on a daily basis. She gained international recognition in 1847 after winning a competition to discover a comet visible only through a telescope, for which she was awarded a gold medal from the King of Denmark. Later, Matthew Vassar recruited Maria as the first professor hired when Vassar College opened in 1865. Her arrival marked the start of a 150-year-long tradition of Vassar professors challenging students to learn by doing. This exhibit highlights research efforts by Maria and her students to record and study the Sun.

They first began recording sunspots by eye in 1868, just a few years after the College opened. Long before the days of Kodak and Polaroid, Maria ventured into the new world of astrophotography by pouring hand-prepared emulsions over glass plates to record astronomical events more precisely than the eye could see. By 1873, Maria began taking daily photographs of the Sun. Using the College's 12" refractor, whose mahogany and brass casing now resides in the Smithsonian's National Museum of American History, Maria projected images of the Sun onto the photographic plates using an apparatus she constructed. She surmised that sunspots were not just clouds on the surface of the Sun, as astronomers had thought, but were whirling cavities. In 1997, 200 photographic plates were re-discovered in a closet of the old Vassar College Observatory (now renamed the Maria Mitchell Observatory and designated a National Historic Landmark),

still in their original envelopes complete with hand-written observational notes by Maria and her students. Although many of the plates are in poor condition through deterioration with age, they provide fascinating insights into astronomy in the late 1800s.

To put Maria's world of astronomy in context, the period of the 1870s was a half-century before several fundamental discoveries. Not till well into the 20th century did astronomers confirm that there were other galaxies besides our own Milky Way galaxy, realize that stars shine because of energy emitted during nucleosynthesis when hydrogen fuses into helium in star cores, and understand that the absorption lines in the spectra of stars and star colors were an indication of their surface temperatures. (Maria once remarked, "I am just learning to notice the different colors of the stars, and already begin to have a new enjoyment." She thought that the colors had to do with different chemical compositions.) Astronomical research in Maria's period largely involved studying astronomical orbits such as stars in binary systems, comets and asteroids in the Solar System, and moons of planets, and making observations of changes in variable stars' brightnesses and markings on planets or the Sun. Maria pursued research in all of these areas, and was one of the first to speculate that Jupiter's bands were the result of storm systems.

Maria led by example, keeping students up past their curfew as they pursued astronomical objects till they sank to the tree-lined horizon in the pre-dawn hours (she once famously asked the campus gardener to trim tree limbs – and eventually the whole tree – so she could continue her observations at low elevation). She escorted students on cross-country trips to view solar eclipses in Iowa in 1869 and in Colorado in 1878. Maria recorded in her journal at the time of the Colorado eclipse, "As the last rays of sunlight disappeared, the corona burst out all around the sun, so intensely bright near the sun that the eye could scarcely bear it; extending less dazzlingly bright around the sun for the space of about half the sun's

diameter, and in some directions sending off streamers for millions of miles...It was now quick work. Each observer at the telescopes gave a furtive glance at the un-sunlike sun, moved the dark eye-piece from the instrument, replaced it by a more powerful white glass, and prepared to see all that could be seen in two minutes forty seconds. They must note the shape of the corona, its color, its seeming substance..." (Maria Mitchell: Life, Letters, and Journals, compiled by her sister Phebe Mitchell).

Some of the plates in this exhibit have envelopes bearing the writing of Mary Whitney, one of the 6 students known as "the hexagon" in Maria's first class. Maria was known as a taskmaster but also much admired and appreciated by the students. She lived at the Observatory (along with her father for many years) and entertained students in her living room directly outside of the dome. She instituted a tradition of hosting a party at the end of each academic year, in which everyone read astronomical poems that they composed. These Dome Parties continue today at Vassar at the close of each semester.

Mary Whitney succeeded Maria as Director of the Observatory. Mary was a prolific writer and published over 100 astronomical papers. Several of Mary's students became prominent astronomers as well. Notable Vassar astronomy alumnae from the late 1800s and early 1900s besides Mary Whitney include Antonia Maury, Margaretta Palmer, Christine Ladd-Franklin, and Caroline Furness. American women in the late 1800s had limited options to pursue astronomy. Most came from Vassar or Wellesley and either stayed at their institution or worked as research assistants at Yale or Harvard or Columbia. These female "human computers" were well regarded for their patience and persistence in tedious work, such as cataloging and categorizing observations of variable stars and stellar spectra. These painstaking observations led to several important discoveries that are fundamental to stellar astronomy today.

Maria noted that "The eye that directs a needle in the delicate meshes

of embroidery will equally well bisect a star with the spider web of the micrometer.” She describes in her diary using real spider web threads to provide a precise narrow line with which to mark the exact position of a star or comet while noting the time of the night. The old Observatory, which now houses the Education Department, has an entryway filled with quotes by Maria Mitchell and photographs of her with her students.

Orbit calculations were a routine part of Maria’s mathematical astronomy courses that were required of all Vassar students. Astronomers understood orbits well enough to know that Venus and Mercury sometimes transit the Sun. In fact, Maria calculated the orbit of Venus as a paid employee for the United States Nautical Almanac. As these inner planets cross the Sun’s surface, they show up as tiny black dots. Several of Maria’s plates on exhibit show these rare events. In one case, she marked the projected path of Mercury across the Sun’s surface. In another, she viewed the transit of Venus with the Sun low in the sky, and partially obscuring trees near the Observatory provide a spider web appearance across the plate. The transit of Venus was a rare occurrence; transits occur in pairs separated by eight years and then repeat after more than 100 years. After the transit Maria observed in 1882, the next transit was in 2012, recorded at the Vassar Class of '51 Observatory by the current Director of the Observatory, Professor Frederick Chromey, and students. Except for the path of Venus across the disk of the Sun, the modern-day photograph and Maria’s photograph are very similar.

Maria once said, “We especially need imagination in science. It is not all mathematics, nor all logic, but is somewhat beauty and poetry.” She would undoubtedly find the library exhibit of her work a fitting tribute to her efforts and her legacy at Vassar.

In February, 1831, I counted seconds for father, who observed the annular eclipse at Nantucket. I was twelve and a half years old. In 1885, fifty-four years later, I counted seconds for a class of students at Vassar; it was the same eclipse, but the sun was only about half-covered. Both days were perfectly clear and cold.

Diary, 16 March 1885

The corona, which is the 'glory' seen around the sun, was visible at least thirteen minutes before totality; each of the party took a look at this, and then all was silent, only the count, on and on, of the young woman at the chronometer. When totality came, even that ceased. How still it was!

Diary, 1878
Denver, Colorado

Exhibition Checklist

UPPER CASES

Case 1

Sunspots, observed by Whitney* & Canfield,
9 October 1885, 12h 10m.

Sunspots, observed by Whitney and Mace,
8 June 1885, ≈12h.

Case 3

Sunspots, observed by Arnold & Stow,
10 November 1873, 12h 17m.

Sunspots, observed by Hodge and Raymond,
7 February 1881, 12h 20m.

Case 5

Sunspots, observers unknown, circa 1874.

Sunspots, observed by Hodge & Whitney,
15 March 1881, 12h 20m.

Case 7

Sunspots, observed by Whitney & Davis,
18 April 1885, 12h 30m.

Sunspots, observed by Whitney & Southworth,
24 April 1885, 11h 58m.

* Mary W. Whitney was a member of the Class of 1868, worked as an assistant to Maria Mitchell, and became chair of the Astronomy Department and Director of the Observatory when Mitchell retired. Frederick R. Chromey, Jr. has been a professor of astronomy at Vassar since 1981. Other observers are listed alphabetically below:

Helen M. Arnold, VC 1874	[Hannah Mace, VC 1890]
Nellie H. Canfield, VC 1887	[Cornelia M. Raymond, 1883]
Lucy Davis, VC 1885	Frances Southworth, VC 1887
Ella Gardner, VC 1887	[Annie T. Spalding, VC ex 1884]
Bertha Hazard, VC 1879	L. A. Stow, VC 1874
E. Carol Hodge, VC 1881	Esther Witkowski, VC 1886

Case 9

Transit of Mercury, observed by Spalding and Hazard,
6 May 1878, 10h 40m.

Transit of Mercury, observed by Spalding and Hazard,
6 May 1878, 13h 26m.

Case 11

Solar Eclipse, observed by Whitney & Witkowsky,
16 March 1885.

Solar Eclipse, observed by Whitney & Witkowsky,
16 March 1885.

Case 13

Solar Eclipse, observed by Whitney & Witkowsky,
16 March 1885.

Solar Eclipse, observed by Whitney & Witkowsky,
16 March 1885.

Case 15

Sunspots, observed by Whitney & Southworth,
30 April 1885, 11h 58m.

Sunspots, observed by Whitney & Gardner,
28 October 1882, 12h.

Case 17

Transit of Venus, observers unknown,
6 December 1882, 1h 42m.

Transit of Venus, observers unknown,
6 December 1882, ≈11h 7m.

Case 19

Transit of Venus, observers unknown,
6 December 1882, 11h 49m 37s.

Transit of Venus, observed by Frederick
R. Chromey, 2012.

LOWER CASES

Case 2

Herschel wedge / Sun diagonal, ca. 1850 — loaned by Debra E. Elmagreen.

“Maculae et faculae ex variis observandi modis stabiliuntur”, illustration from Christoph Scheiner’s *Rosa Ursa*, Bracciani: Apud Andream Phaeum typographum Ducalem, 1630 — original at Houghton Library, Harvard University.

Story, Alfred T. *The Story of Photography*. New York: McClure Phillips, 1974 (reprint of the 1904 edition).

Case 4

“Observations with the twelve inch equatorial by Professor Mitchell, 1866 April 13 - 1877 June 17”, Mitchell notebook — Mitchell Papers.

Photograph of Maria Mitchell and Mary W. Whitney with Vassar’s twelve inch equatorial telescope, 1889 — Vassar College Archives Files.

Photograph of the equatorial in its current home at the National Museum of American History — “DC pics 084” by How I See Life, via Flickr, CC BY-ND.

Case 6

Refracting telescope, circa 1900 — loaned by Debra E. Elmagreen.

Glass plates and sleeves, ca. 1875-1885 — Mitchell Papers.

Illustration from Arabella B. Buckley’s *Through Magic Glasses, and Other Lectures...* London: E. Stanford, 1890.

Case 8

Student notebook, Mary Scott, VC 1876 — Student Materials Collection.

Photograph of the Senior Astronomy Class in Classroom, 1878 — Vassar College Archives Files.

Mitchell, Maria. *The Collegiate Education of Girls*. Boston: New England Publishing, 1881.

Case 10

Whitall, Henry. *A Moveable Planisphere of the Heavens at Every Minute*. New York, 1862

Chauvenet, William. *A Manual of Spherical and Practical Astronomy*. Philadelphia: Lippincott, 1874.

Case 12

Mitchell's notes on the 1885 eclipse — Mitchell Papers.

Case 14

"Report of Miss Mitchell" in *Observations of Solar Eclipse of August 7, 1869, at Burlington, Iowa*.

Mitchell, Maria. "The Total Eclipse of 1869", *Hours at Home*, October 1869.

Photograph taken by W. G. Chamberlain: Mitchell and her students at the 1878 eclipse, Denver, Colorado — Vassar College Archives Files.

Case 16

Champney, Elizabeth. *In the Sky Garden*. Boston: Lockwood & Brooks, 1877.

Mitchell, Maria. "The Astronomical Science of Milton: As Shown in 'Paradise Lost'." *Poet Lore*, vol. 6, 1894.

Case 18

Instructions for Observing the Transit of Venus. Washington: Government Printing Office, 1882 — Mitchell Papers.

"Venus. Transit, Dec 6, 1882", Mitchell notebook — Mitchell Papers.

Photograph of the Transit of Venus, Dec. 1882 — Mitchell Papers.

Case 20

Gauss, Carl Friedrich. *Theoria Motvs Corporvm Coelestivm in Sectionibvs Conicis Solem Ambientivm, Hambvrgi, Svmtibvs F. Perthes et I.H. Besser*, 1809. This copy inscribed from Maria Mitchell to Mary W. Whitney (1868), and from Whitney to Caroline E. Furness (1921).

A Catalogue of the Exhibition

Seeing the Sun
Maria Mitchell's
Observations, 1868-1888

At the Frederick Ferris Thompson
Memorial Library
January—June 2016

Curated by
Laura Streett, College Archivist and
Debra Meloy Elmegreen,
Professor of Astronomy on the
Maria Mitchell Chair

The logo for BRIDGING features the word "BRIDGING" in a bold, white, sans-serif font. The text is centered within a dark gray, horizontally-oriented rectangular shape that has a slight wave or curve at its top edge.

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