Celestial Observers

The First Sixteen Berkeley Women Doctoral Graduates in Astronomy: 1913-1952

Comet Morehouse (aka 1908c) photographed by A. Estelle Glancy from Mount Hamilton using the Willard lens on the Crocker Telescope, November 14, 1908; scan from the original glass-plate negative, Courtesy of UCO/Lick Observatory

By Sheila M. Humphreys

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Astronomy is the oldest of the sciences. Ethnoastronomists confirm that North American Indians were deeply influenced by astronomy; they farmed, hunted, and gathered according to their observation of the sky. When academic astronomy came to North America in the nineteenth century, it followed the long tradition of European universities, although it lagged behind Europe where many observatories existed by 1800.
In America a regional observatory was built as early as 1831 at the University of North Carolina. President John Quincy Adams waged a twenty-year rhetorical campaign to advocate that Congress use the Smithson bequest[1] to construct a federal observatory. At a public lecture delivered in Boston advocating for a national observatory in 1839, Adams wrote in his diary that "the hall was crowded to its utmost capacity with two or three women to the men."[2] The US Naval Observatory was built in Washington, D.C. in 1844. Astronomy was taught at Berkeley from its founding and was required for engineering students. Among the first twenty doctorates granted to women at Berkeley, five were in astronomy. Women earning PhDs in astronomy in the early years of the twentieth century exceeded the number of those in mathematics. However, the first women graduating with advanced training in astronomy faced constraints as they pursued careers in astronomy. Access to certain telescopes was limited. Attitudes toward marriage and the expectation that women would retreat to raise families narrowed possible options. Equally problematic was the perception of women as physically fragile.

Invariably the pioneering women who pursued astronomy positions were underemployed because they were initially hired as *computers*. *Computer* is a job title referring to a person, usually a woman, who performed painstaking, tedious calculations as assistants to male astronomers during the day. Computers were usually well-educated women who processed data generated by men, rather than making their own direct observations of the skies. A brilliant computer was Annie Jump Cannon, a Wellesley graduate who supervised a large group of computers at the Harvard Observatory. She is recognized for creating the stellar classification system still used today.[3] An equally consequential but unrecognized astronomer at Harvard, part of Professor Pickering's "harem" of computers, was Henrietta Swan Leavitt, a Radcliffe graduate (1892) who identified over 1200 variable stars. She discovered the period-luminosity relationship in Cepheid-type variable stars, groundbreaking research which provided a critical means of measuring astronomical distances. Leavitt's work laid the foundation for the discoveries of astronomer Edwin Hubble, who discovered that the spiral nebula Andromeda is actually a galaxy and that the Milky Way is just one of many galaxies.[4] Swan, like Estelle Glancy who followed her, was deaf and died at 53 of cancer.

In Southern California women were apparently barred from using larger telescopes at Mount Wilson.[5] Their presence in observatories at night was deemed questionable, a policy justified because of the lack of separate facilities. While many women graduate students of the period 1900 through 1940s held the title of Assistant or Instructor in Astronomy at Berkeley, none held

[1] James Smithson (1765–1829), was a British scientist who left his estate to the United States to found "at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge."
[2] Portolano, Marlana. "John Quincy Adams's Rhetorical Crusade for Astronomy." *Isis*, vol. 91, no. 3, 2000, pp. 499.
[3] Annie Jump Cannon (1863-1941) https://www.space.com/34707-annie-jump-cannon-biography.html
[4] Henrietta Swan Leavitt (1868-1921) https://www.aavso.org/henrietta-leavitt-—-celebrating-forgotten-astronomer
[5] Berkeley PhD astronomer Elizabeth Scott documented this practice in her oral history: Elizabeth Scott. "Oral History, the Women's Faculty Club of the University of California, Berkeley, 1919–1982." Regional Oral History Office, Bancroft Library, University of California, Berkeley, 1983, 149.

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a tenure-track position.[6] Berkeley's Astronomy Department did not hire its first tenure-track woman faculty member, Imke De Pater, until 1984.[7]

View from Mount Hamilton Road

The development of astronomy at Berkeley is inextricably tied to the Lick Observatory on the 4200-foot summit of Mount Hamilton, east of San Jose, 19 miles up a winding road from town. Built with private funds given by James Lick, the "Lick Astronomical Department" observatory opened in 1888 to world-wide attention. In her 1892 history of the Lick Observatory, Millicent Shinn called it "the crowning possession of the University with the largest telescope on earth" and equal to the Harvard Observatory.[8] Lick was the first permanently occupied mountaintop observatory. Remote from Berkeley and at a high altitude, astronomers and students could work under the clear, dark skies and steady atmospheric conditions optimal for observing. After the observatory was turned over to the Regents of the University of California in 1888, its state-of-the-art telescope made possible the development of a first-rate astronomy program at Berkeley. From the beginning, graduate students were integrated into the residential observatory community as Lick Fellows. The long journey from Berkeley to the mountaintop also meant students, women and men, joined a close community on the mountain for weeks at a time. "No student need leave California to get the highest training in astronomy," declared Shinn. After four years, the small staff of Lick astronomers had already published 462 papers.

Women's colleges in New England like Vassar, Smith, Mount Holyoke, and Wellesley, built observatories in the late 19th century and were an important source of both astronomy graduate students and of faculty positions. Students at women's colleges were taught mostly by women faculty. Maria Mitchell (1818-1889, the first American woman astronomer, and in 1847 the first American to discover a comet, was the best-known woman scientist of the nineteenth century.[9] She went on be the first woman faculty member in astronomy and created a strong program at the undergraduate and master's level at Vassar College. As director of the observatory, Mitchell was followed by three generations of women observatory directors at Vassar. The first two women to earn PhDs in astronomy at Berkeley graduated from Vassar and Wellesley,

[6] Examples: Adelaide M. Hobe was an Assistant who worked without pay from 1900 to 1922.
[7] Imke De Pater, https://astro.berkeley.edu/people/ike-de-pater
[8] Millicent W. Shinn. "The Lick Astronomical Department of the University of California" Reprinted from the *Overland Monthly,* 1892. Shinn, a Berkeley alumna, was editor of the *Monthly.*
[9] The Mitchell crater on the moon is named for her. https://www.aps.org/publications/apsnews/20060/history/cfm

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respectively, where they were given access to telescopes and the encouragement of women faculty. In turn, women doctoral graduates in astronomy found academic jobs at women's colleges upon completion of their degrees. Six of the first women PhDs profiled spent part of their careers teaching at women's colleges. In the following pages, I offer a summary of the education and careers of the sixteen women who earned doctorates at Berkeley, in order of the degrees conferred beginning with first two in 1913.

First Sixteen Women Doctoral Graduates in Astronomy (1913-1952)

Year	Name	Undergraduate Institution	Employment
1913	Phoebe Waterman (Haas)	Vassar College	Citizen Scientist, AAVSO
1913	Anna Estelle Glancy	Wellesley College	Natl. Observatory, Argentina, American Optical
1920	Sophia Levy (McDonald)	UC Berkeley	Math Dept, UC Berkeley
1921	Priscilla Fairfield (Bok)	Boston University	Smith College, Harvard Observatory
1921	Jessica May Young (Stephens)	Washington University	Washington University
1923	Edith Cummings (Taylor)	University of Missouri	Lick Observatory
1925	Mary Heger (Shane)	UC Berkeley	Lick Observatory, Los Alamos
1930	Maud Worcester (Makemson)	UCLA	Vassar, UCLA, NASA
1930	Lois Tripp Slocum	Smith College	Smith, Wilson College
1931	Charlotte Moore (Sitterly)	Swarthmore College	Princeton, Nat'l. Bureau of Standards
1932	Phyllis Hayford (Hutchings)	Northwestern University	Rollins, Whitman College
1933	Katherine Prescott (Kaster)	UC Berkeley	Lick Observatory
1937	Dorothy N. Davis (Locanthi)	Vassar College	Vassar, Beckman Instruments, Caltech, JPL (part time)
1946	Martha Stahr (Carpenter)	Wellesley College	Wellesley, Cornell, University of Virginia
1949	Elizabeth Scott	UC Berkeley	Math and Statistics Depts, UC Berkeley
1952	Helen Pillans	University of Chicago	Hollins, Mt. Holyoke, Mills College

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Phoebe Waterman ascending solar tower at Mt. Wilson in a "bucket"
(Photo: National Air and Space Museum)

Phoebe Emma Waterman (Haas) (1882–1967)

Two women earned the first doctoral degrees in astronomy on the same day in 1913. Phoebe Waterman was the daughter of a US Army cavalry officer. While visiting her father in 1900 in Cuba, she was excited to observe a partial solar eclipse. Waterman studied astronomy at Vassar College where she earned a BS and an MS in astronomy in 1905 and 1906. She wrote her MS thesis on "The Definitive Orbit of Comet 1880." Waterman studied with Professor Caroline Furness, a Columbia PhD who became her lifelong mentor. Before being accepted to Berkeley's graduate program, Waterman worked for two years as a *computer* at the Mount Wilson Laboratory, near Pasadena, supervised by acclaimed astronomers like George Ellery Hale and J. C. Kapteyn. She chafed at her assigned tasks of classification of photographic plates and reduction of stellar spectra and found little chance for independent work.

Waterman realized she needed advanced training to achieve her ambition to make her own observations, and so she applied for graduate study at Berkeley. Once enrolled in 1910, she commented about the difference between Vassar and Berkeley, and the new experience of competing with men. Waterman wrote to Furness: "… they give a woman the same work as the men. I am getting used to the different standard a little—for it surely is a different one, and quite a different thing from measuring up against women." Her professors thought she was as capable as any man. Armin Otto Leuschner, the department chair who built Berkeley's astronomy program, described Waterman as "one of the most unusually well-equipped women we have ever had at Berkeley. She is brilliant, quick and accurate and disposes of her work with promptness and accuracy."[10] She wrote a PhD thesis on "The Visual Region of the Spectrum of the Brighter Class A Stars." Waterman was one of the first woman astronomers to conduct her own telescopic research instead of relying on the observation logbooks of others. Alongside fellow graduate students, she conducted research at the Lick Observatory; records of her observations appear in

[10] These quotes are drawn from Smithsonian National Air and Space Museum, "Introducing the Phoebe Waterman Haas Public Observatory," July 16, 2013. https://www.airspacemag.com/space/womans-fight-for-the-stars-180969500/

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the Lick Observatory Archives.[11] After graduation, Phoebe Waterman and her roommate, Estelle Glancy, (profiled next) accepted positions at the Argentine National Observatory in Cordoba, an outpost of the Lick Observatory, directed by the American Charles Perrine, former Lick staff member. Fate intervened; during the voyage to Argentina. Waterman fell in love with an American businessman, Otto Haas. Once in Cordoba, she found the work to be routine and boring, and soon returned home to marry Haas. Like Berkeley mathematician Emma Lehmer, she gave up an independent career as a promising astronomer to marry and raise a family. Nonetheless, Haas bought a telescope in 1927 and recommenced observational astronomy for several years. When her two sons were older, she tried to reenter the field but reported she was discouraged by Berkeley faculty. At the suggestion of her Vassar mentor, Caroline Furness, Haas volunteered to observe variable stars for the American Association of Variable Star Observers at Harvard Observatory (AAVSO), an organization devoted to scientific discovery through variable star observations, which encouraged volunteers and amateur astronomers.. As a citizen scientist Haas continued involvement in astronomy through her scientific observations and calculations. Haas submitted 338 observations to AAVSO between 1928 and 1933. In 1941 she wrote "Someday I hope I can join in again…. There is nothing I enjoy more than an evening out with my telescope, the thrill of finding a faint prick of light where last time I looked, I could see nothing, then seeing that point brighten. I'll be at it again yet!"[12] Although Haas sustained her passion for astronomy as an observer and volunteer computer, she never attained a professional position. In 1945, after World War II, Phoebe and Otto Haas founded the Phoebe Waterman Foundation to help children who had lost fathers in the war, and to support educational institutions. Her grandson, Thomas Haas, donated $6 million in 2013 to support science education through the Phoebe Waterman Haas Public Observatory at the National Air and Space Museum. As a result, Phoebe Waterman Haas is far better known than her classmate Estelle Glancy.

Anna Estelle Glancy (Photo: American Optical Society)

"Opportunity Knocked at my Door"

[11]Records of Berkeley student observations and calculations, including those of Berkeley students Waterman, Glancy, Levy, Fairfield, Young and Taylor are archived at the Lick Observatory Archives: http://collections.ucolick.org/archives_on_line/search_ms.html

[12]Thomas R. Williams. "Phoebe Haas- An AAVSO Volunteer" Journal of American Association of Variable Star Observers, vol. 20, 1991, 18-22.

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Anna Estelle Glancy (1883–1975)

Estelle Glancy earned a BA in astronomy at Wellesley College in 1905. Wellesley, like Vassar, had a strong astronomy program. Glancy received her PhD in astronomy from UC Berkeley the same day as her roommate, Phoebe Waterman, in 1913. Graduate study at Berkeley was serendipitous. When she failed to find a job, Glancy explained: "After an idle period of nearly a year and no success in selling my poor talents at an eastern observatory, I launched a far distant appeal to the Berkeley Astronomical Department …I was invited to come as a computer provided I would also work toward a PhD degree; a thought which would never have entered my mind."[13] She arrived in 1906 shortly before the San Francisco earthquake and fire.

Glancy's research advisor, Armin Leuschner, called her "brilliant, industrious and accurate." Like Waterman, she was a fellow at the Lick Observatory, where a record of her observer's notebooks and instrument logbooks are archived.[14] According to Lick archivist Tony Misch, Estelle Glancy is considered the first woman to do her own research at Lick. Her groundbreaking achievement "was the splendid series of glass-plate photographs she made from Mt. Hamilton of comet Morehouse using the Crocker telescope."[15]

Comet Morehouse (aka 1908c) photographed by A. Estelle Glancy from Mount Hamilton using the Willard lens on the Crocker Telescope, November 14, 1908; scan from the original glass-plate negative, courtesy of UCO/Lick Observatory

[13] All the quotes by Estelle Glancy are taken from her autobiographical account in: Dick Whitney. "Estelle Glancy: 1918-1951" Optics and Photonics News**.** Vol. 28, 3, 40-47.

[14] Records of Lick Observatory faculty and student observations and calculations, including those of Waterman and Glancy, are archived at the Lick Observatory archives: http://collections.ucolick.org/archives_on_line/search_ms.html

[15] Personal communication, Tony Misch, Director, Lick Observatory Historical Collections Project, June 27, 2021.

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After earning her PhD, Glancy could not find a position as an astronomer in the United States, so she traveled with Phoebe Waterman to accept a position as an assistant astronomer with the Argentine National Observatory. She was considered by W.W. Campbell for the position of director of the southern observing station in Santiago, Chile, but as one recommender wrote "Too bad A. E. Glancy has not Alfred instead of Anna as her first name."[16] Glancy remained for four years but with the onset of World War I she returned to her native New England. Still finding no position in astronomy, Glancy decided to migrate from astronomy to optics and "start from scratch." She spent the rest of her career as a successful geometric research optician at American Optical Company in Southbridge, Massachusetts. Like other female employees, she first functioned there as a computer. "I had no illusions about the difficulty of transfer from Astronomy to Optics but knew also that there was no better background than computing in astronomical problems. So I elected to start once more from scratch. Trigonometry, calculus, the art of computing and something, which is best called insight, which developed under the inspired teaching of Professor Leuschner, was my stock in trade. In exchange, the new job could give me association with top-flight leaders and a chance to grow…."

Her boss at American Optical for 33 years was a former astronomer, Dr. E. D. Tillyer, well known as a leading lens designer. During WWI American Optical was requisitioned to fill large military orders for lenses, which were calculated by Glancy. In her role as a geometric optician, she worked on numerous lens designs and was responsible for performing the complex mathematical calculations involved in ophthalmic optics.

Great 36 Inch Refractor (Photo: Lick Observatory Archives)

"When the war ended, I began the long and repetitious calculations on which the Tillyer spectacle lens is based. In principle, this lens aims to give marginal vision as nearly like vision through the center of the lens as possible. The larger part of ten years was occupied in this major project which no other company than the American Optical Company was ready to undertake."

A decade of mathematical calculations was essential to the Tillyer corrected curve lens, to which Estelle Glancy's name should have been appended. Glancy was awarded a patent in 1923 for her

[16]John Langford. *American Astronomers.* Chicago: 1997, 292.

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design of the first progressive lens for eyeglasses, an impactful innovation to correct for near and distant vision as an alternative to bifocal and trifocal lenses. She also designed lenses for microscopes, cameras and military optics. Between 1929 and 1945 Glancy received thirteen patents for her innovations. Glancy was the first among her Berkeley women peers to find employment in industry, but she continued to write astronomy papers with her advisor Arnold Leuschner.[17] As of 1950, Glancy was the sole woman lens designer in the world. In retirement she cited her progressive deafness as a factor in her success. "The forced aloneness which deafness imposes was compensated in part by freedom from distraction and the ability to concentrate." She modestly concludes the account of her career: "Opportunity knocked at my door…."

Sophia Hazel Levy (Photo: Berkeley Mathematics Department)

Sophia Hazel Levy (McDonald) (1888–1963)

Sophia Levy, the daughter of California pioneers, developed an interest in astronomy as a Berkeley undergraduate. She earned two degrees in astronomy at Berkeley, a BS in 1910 and a PhD in 1920. Like Waterman and Glancy, she was advised by Armin Leuschner. Her dissertation focused on the motion of comets and minor planets, a subject she continued to pursue. For most of her career, however, Levy taught on the mathematics faculty at Berkeley. While pursuing her doctorate, she was hired as an astronomy assistant from 1910-1914. After that she worked in two administrative jobs, presumably to support herself, as assistant to the dean of the Berkeley Graduate Division and Secretary to the California State Board of Education for the Commission of Credentials. In 1921 Levy was hired as instructor in astronomy for two years. Levy continued to contribute papers in theoretical astronomy, some co-authored with Leuschner even as late as 1952.[18] Because of her ability in the field of numerical analysis, she was appointed instructor in mathematics in 1921 and promoted to assistant professor in

[17]Paul Herget. "Armin Leuschner: A Biographical Memoir". Washington DC: National Academy of Science, 1978.
[18]Armin Leuschner with Anne Estelle Glancy and Sophia H. Levy. "Tables of minor planets discovered by James C. Watson. Part II. On v. Zeipel's theory of the perturbations of the minor planets of the Hecuba group. Sci. Mem. Nat. Acad. Sci., 14(3): 1-15, 1922."

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1924. Eventually Levy rose to full professor of mathematics in 1949, *twenty-six years later*. During World War II, Levy directed a program of mathematics instruction for the Army Specialized Training Program at Berkeley. She taught military courses on antiaircraft gunnery and even published a text, *Introductory to Artillery Mathematics and Antiaircraft Mathematics*.[19]

Levy cared deeply about improving the quality of mathematics instruction at the secondary school level and assumed leadership roles in the training of prospective math teachers. She advised the State of California on the math curriculum for the California Committee for the Study of Education in California public schools. She served as chair and sectional governor of the newly organized Northern California Section of the Mathematical Association of America. In 1941, the Northern California and Southern California Sections established a Joint Committee on Mathematical Education under Levy's chairmanship "to study means of strengthening the program of mathematics in schools and colleges." Levy designed a summer session for math teachers to meet state requirements and published articles in *The Mathematics Teacher* about teaching mathematics in the schools. According to Professor Calvin Moore's history of the Berkeley Mathematics Department, Sophia Levy's leadership in pre-college teaching and work with the School of Education were highly valued.[20] Levy chose to defer her marriage to her math colleague John McDonald until he retired in 1944 because, under anti-nepotism rules, one of the two would have had to resign from the faculty had they married. Anti-nepotism rules were not dropped until the 1971. A memorial written by Levy's colleagues affirms the importance of her work and influence on mathematics education: "She contributed to the fame the astronomy department had enjoyed under Professor Leuschner in the field of celestial mechanics, and she contributed significantly to the teaching of mathematics in the schools and colleges of California."[21]

[19] Sophia Hazel Levy, *Introductory Artillery Mathematics and Antiaircraft Mathematics* (Berkeley: University of California, 1943).
[20] Calvin Moore. *Mathematics at Berkeley.* Wellesley: A.K. Peters, 2007, 68.
[21] V.F. Lenzen, S. Einarsson and G. Evans. In Memoriam. Sophia Levy McDonald. University of California, April 1965.

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Jessica May Young Stephens (Photo: Washington University)

Jessica May Young (Stephens) (1893-1961)

Jessica May Young was reared in St. Louis, Missouri, and earned a bachelor's in 1914 and master's degree in 1915 in astronomy and physics at Washington University. She wrote an MS thesis "On the Cause of the non-appearance of certain periodic comets on their predicted returns." Young enrolled at UC Berkeley to pursue a PhD in astronomy, which she earned in 1920, with a thesis on the orbits of comets and binary stars. The fourth woman astronomy doctorate at Berkeley, Young briefly taught physics and astronomy at College of St. Teresa in Minnesota and at Northwestern University. Returning to Missouri, she was hired as Instructor of Math and Astronomy at her alma mater. Sometimes known as "Mrs. Stephens" after her marriage to Eugene Stephens, a colleague in the math department, Stephens made frequent trips from St. Louis back to Lick Observatory for study and research. In 1923 she was advanced to Assistant Professor of Mathematics and Astronomy, the level at which she remained until she became the first woman in astronomy promoted to Associate Professor in 1952, 32 years after her first appointment. Stephens enjoyed a robust and successful teaching career. Washington University archives reveal that Stephens promoted appreciation for astronomy through public lectures during the 1940s and occasionally wrote popular articles for the St. Louis Post Dispatch. In April 1940, for example, Stephens issued a bulletin announcing the spectacular visibility of Venus, Saturn, and Mars. The St. Louis papers reported that Stephens accompanied her students to the campus observatory to view eclipses of the moon in 1942 and 1947. Jessica Stephens was honored in 1952 by the Business and Professional Women's Club of St. Louis as one of eight outstanding women "Rampart Builders." Dr. Stephens retired as Associate Professor Emerita in 1958. To mark her retirement, Washington University hosted a "Tea in honor of Mrs. Stephens." She accepted one last teaching post in astronomy at North Carolina Agricultural and Mechanical College.

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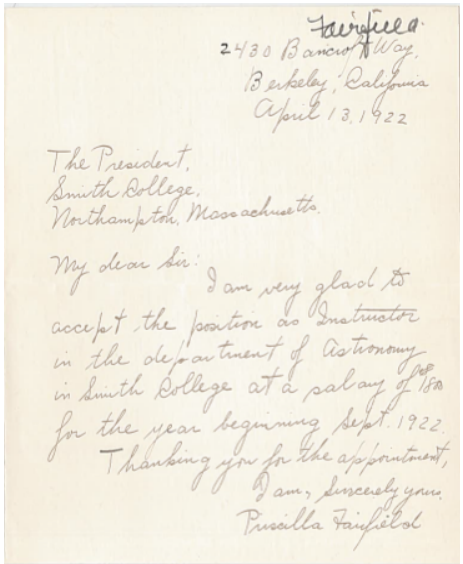
Priscilla Fairfield

Priscilla Fairfield (Bok) (1896-1975)

Priscilla Fairfield's career in astronomy is intimately linked with that of her husband, Bart Bok. She grew up outside of Boston and was fascinated by the sun as a child. The daughter of a Unitarian minister, Fairfield worked throughout college to pay her tuition at Boston University. It is said that she bribed a nightwatchman to allow her to use the telescope on the roof. At the age of twenty, Fairfield wrote an article on her observations for *Popular Astronomy*. She enrolled for a doctorate in astronomy at Berkeley, where she was one of the last students of Professor William W. Campbell, Director of the Lick Observatory, and a future president of the University of California. She finished her degree in 1921 and accepted a position as assistant professor of astronomy at Smith College for a salary of $1800. Known in the Smith course catalogue as "Miss Fairfield," she taught Introduction to Astronomy and Astronomy 11, which required three to four hours of observing weekly.



Fairfield
2430 Bancroft Way,
Berkeley, California
April 13, 1922

The President,
Smith College,
Northampton, Massachusetts.

My dear Sir:

I am very glad to accept the position as Instructor in the department of Astronomy in Smith College at a salary of $1800 for the year beginning Sept. 1922.

Thanking you for the appointment, I am, Sincerely yours,
Priscilla Fairfield

General Electric had rejected her job application because she revealed her aspiration to be an astronomer. In her nine years at Smith, Priscilla Fairfield advanced to the rank of associate professor.

In 1928 Fairfield traveled to Leiden, The Netherlands, to attend the International Astronomical Society meeting. There she met Bart Bok, a Dutch astronomy graduate student ten years her junior, who was assigned as her host. Bok fell in love immediately. After a year of correspondence, Bok interrupted his own doctoral research in Holland and moved to Harvard. Three days after his arrival, Fairfield and Bok were married. Theirs was a felicitous union, personally and professionally. While Bok rose to full professor at Harvard, Priscilla Bok continued collaborating with him in their research without pay or title for forty years. She stayed home to raise their two children but continued to do research. Women astronomers, mostly faculty at

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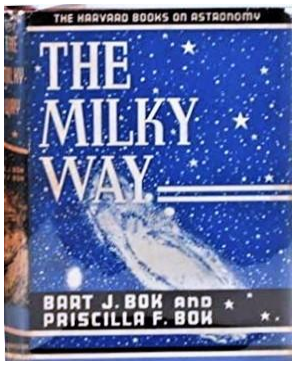
women's colleges, gathered at intervals through the 1940s, and Fairfield's name appears regularly as a participant on the rosters of the meetings.

In his oral history, Bart Bok says, "My wife Priscilla did a lot of work at Harvard and didn't even want a job."[22] Their scientific achievements are completely entwined. In the Royal Astronomical Society obituary for Bok, the author states "…it is difficult and pointless to separate his achievements from hers."[23]

The Boks jointly wrote many journal articles on stellar magnitudes, star clusters, and the structure of the Milky Way. The textbook they published in 1941, *The Milky Way*, was immensely popular and was revised and republished in five subsequent editions and many languages.[24] As galactic astronomy rapidly evolved, they continuously revised the text. The Boks were interested in sharing their discoveries with the public and were called the "salesmen of the Milky Way" by the Boston Globe.



After twenty-five years at Harvard, the Boks left for Australia where Bok was named Director of the Mount Strombo Observatory in Canberra. He installed a new telescope there and a field observatory and initiated a graduate program in astronomy. He had little time for research, but Priscilla Bok devoted herself to nocturnal observations to determine stellar positions, and data analysis during the day. After nine years, the Boks made a final move to Arizona, where Bart directed the Steward Observatory from 1966-1970. Priscilla Bok died in 1975.[25]

The Priscilla asteroid (2137, a Main-belt asteroid), named for her, was discovered on August 24, 1936 by K. E. Reinmuth at Heidelberg, Germany. The Priscilla Fairfield Bok Prize, established in 1966 at the Australian National University, is awarded annually to a third-year female science student. In recognition of their dedication to the public understanding of science, other awards in the name of both Bart and Priscilla Bok have been established by the American Astronomical Society and the Astronomical Society of the Pacific, given at the Intel International Science and Engineering Fair. A recent book entitled *Women of the Moon: Tales of Science, Love, Sorrow and Courag*e (2019) devotes a chapter to the marriage and achievements of Priscilla Bok but adds little to what is already known.[26]

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[22] Oral History Interview with Bart Jan Bok, May 15-19, and June 14, 1978. American Institute of Physics, 1978. Bart Bok's academic career, with references joint work with Priscilla Bok, are included.

[23] Bart Bok Obituary. http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?bibcode=1987QJRAS..28..539L&db_key=AST&page_ind=0&data_type=GIF&type=SCREEN_VIEW&classic=YES

[24] Bart J. Bok and Priscilla F. Bok. *The Milky Way*. Harvard University Press: 1941; 5th edition 1981.

[25] For a full account of Bart Bok's academic career, with references to joint work with Priscilla Bok, see his oral history: Oral History Interview with Bart Jan Bok, May 15-19, and June 14, 1978. American Institute of Physics, 1978. See also:

[26] Daniel R. Altschuler and Fernando Ballesteros. *The Women of the Moon: Tales of Science, Love, Sorrow and Courage.* J. Ballesteros. Oxford University Press, 2020.

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Edith Cummings (Savitar Yearbook 1917, University of Missouri)

"…unfortunately she is not a man."

Edith Eleanor Cummings (Taylor) (1894-1979)

Edith Cummings was born in Beatrice, Nebraska and attended the University of Missouri. She graduated Phi Beta Kappa in 1915 with a bachelor's and in 1917 with a master's degree in astronomy. Cummings was recognized as a gifted student. She conducted research with Professor Robert Horace Baker under whom she wrote a master's thesis entitled "The eclipsing binary TV cassiopeiae," which was published in the Laws Observatory journal in 1918. In recognition of the distinction of her thesis Cummings was awarded the Laws Astronomy Medal in 1916. Professor Baker hired her as his research assistant from 1915-17 and they co-authored several publications. Baker wrote in his recommendation letter for graduate school: "As an undergraduate Miss Cummings was the most promising student I have had…while unfortunately she is not a man, I believe she is hampered by her sex less than any aspirant I have known. In our extrafocal work she has done a man's share. She has unlimited energy, health and strength to accompany it. She intends to make astronomy her life's work."[27] Cummings earned her PhD in astronomy from Berkeley in 1923. During her graduate years at Lick Observatory, she co-authored at least two publications with her contemporary Priscilla Fairfield.[28] Cummings built a photoelectric photometer, an instrument deemed highly innovative, used to measure the intensity of starlight work. This was an unusual achievement for a woman. Her doctoral thesis was entitled "The Photoelectric Photometer of the Lick Observatory and Some Results Obtained with it." This research was published in 1924 in the Lick Observatory Bulletin.[29] In 1922 Edith Cummings married William Halvor Taylor, a physics graduate of Ripon College, and gave birth to a daughter the following year. She moved to Wisconsin with her husband who worked for the Bureau of Standards; they later divorced. After several years Edith Cummings Taylor appears to have lost touch with astronomy despite her accomplishments and her vow to make astronomy her life's work.[30]

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[27] Charles Peterson. *An informal history of the Astronomy Department.* University of Missouri, 1981.
[28] https://ui.adsabs.harvard.edu/abs/1920PASP...32Q..67C/abstract
[29] Shane, M. L, & Calciano, E. S. (1969). *Mary Lea Heger Shane: The Lick Observatory*
[30] Peterson, ibid, 64.

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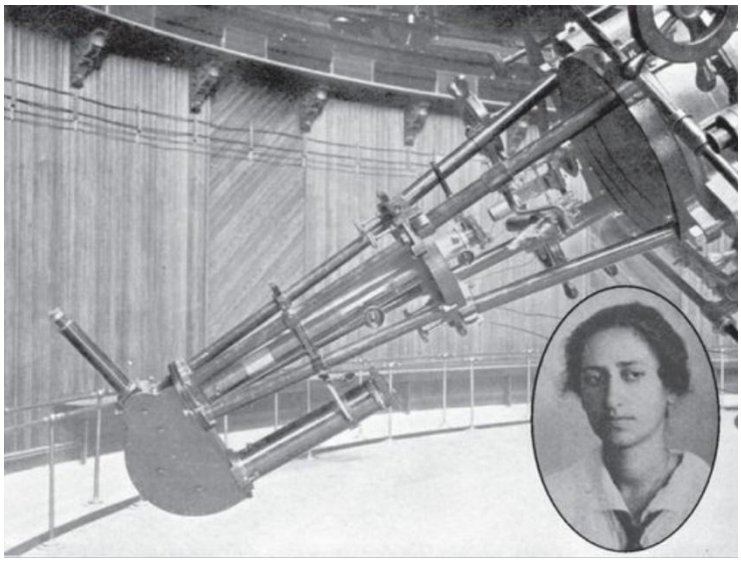
Group in Stream. l. to r. Amy Marshall, Robert Trumpler, Donald Shane, Edith Cummings, Priscilla Fairfield. Lick Observatory Records: Photographs. UA36 Ser.7. Special Collections and Archives, University Library, University of California, Santa Cruz.



A photograph, reproduced from Campbell, of the original Mills spectrograph on the 36-inch refractor at Lick Observatory as used by Mary Lea Heger for her observations of the first DIBs. The image of Heger, from the 1919 *Blue & Gold Yearbook*, is courtesy of the Bancroft Library, University of California at Berkeley.

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"The thesis came and said... *'take me'"*

Mary Lea Heger (Shane) (1897-1977)

Mary Lea Heger grew up in Belvedere, across the bay from San Francisco. She majored in astronomy at Berkeley as an undergraduate, class of 1919 and received her PhD in Astronomy in 1924. As an undergraduate, Heger enjoyed the small classes and friendliness of the astronomy professors. During her senior year she was hired as a teaching assistant to instruct celestial navigation to naval officers. In her oral history Heger states that her pursuing an astronomy doctorate was accidental. While aiming to obtain some observatory experience at Lick, she discovered that an idea she had while an undergraduate "just panned out…and became a ready-made thesis." "I don't think I meant to take a PhD when I went up" to Mount Hamilton in 1919.[31] Unlike the usual progression from coursework to research, she conducted observations at Mount Hamilton during her first year in the doctoral program. Describing her research problem as "irresistible" she said, "It was as though the thesis came and said, '*Take me'*." Heger is credited with a major discovery: observing and researching the Diffuse Interstellar Bands 5780 Å and 5797 Å fifteen years before her contemporary P.W. Merrill, a fellow Berkeley PhD astronomer who spent his career at Mt. Wilson. She was one of the first people to detect sodium atoms in interstellar space and in doing so initiated "a substantial field of research."[32]

Mary Lea Heger married fellow graduate student Donald Shane in 1920, just after Donald finished his PhD in astronomy. The significance of Heger's doctoral research makes one wonder what she would have accomplished, had she not given up her research career in astronomy to raise children and support her husband's work. Their son Whitney Shane was born in 1928 and graduated from Berkeley in 1951. An observational astronomer whose career was in the Netherlands, Whitney Shane conducted research in structure and dynamics of galaxies.
While Donald Shane served as the Director of the Lick Observatory from 1945-58, Mary Shane acted as the "scientific hostess" of the observatory community, welcoming astronomers from all over the world, apparently with grace and generosity. Shane describes the liveliness and warmth of the Lick community and life on Mount Hamilton in her oral history, which included square dances, hikes and picnics, and preparing Christmas dinners for families of staff and faculty on the mountain. The children of faculty and staff attended a one-room school there. During the Second World War, Shane accompanied her husband to Los Alamos, where she worked as a computer in theoretical physics and he worked on the Manhattan Project. Toward the end of her husband's tenure at Lick, Mary Shane discovered dilapidated boxes in the attic of the Observatory which contained correspondence, handwritten scientific copy books, albums, and other memorabilia, which motivated her to spend five years organizing what became a historic archive of the Lick Observatory. "Under her leadership and with her active participation, a group of dedicated volunteers identified, classified, and catalogued thousands of letters, clippings, and photographs. Letters from almost every notable American astronomer since Simon Newcomb, as well as from many European scientists, can be found in the Shane Archives."[33] The Mary Heger

[31] Shane, M. L, & Calciano, E. S. (1969). *Mary Lea Heger Shane: The Lick Observatory*.
[32] Tony Misch pointed out the impact of Heger's research, documented in this article: Benjamin McCall and Elizabeth Griffin. "On the Discovery of Diffuse Interstellar Bands," 2013. https://royalsocietypublishing.org/doi/full/10.1098/rspa.2012.0604
[33] S. Vasilevskis and D. E. OsterBrock. *Charles Donald Shane: Biographical Memoir*. National Academy of Science, Washington D.C. 1989, 506.

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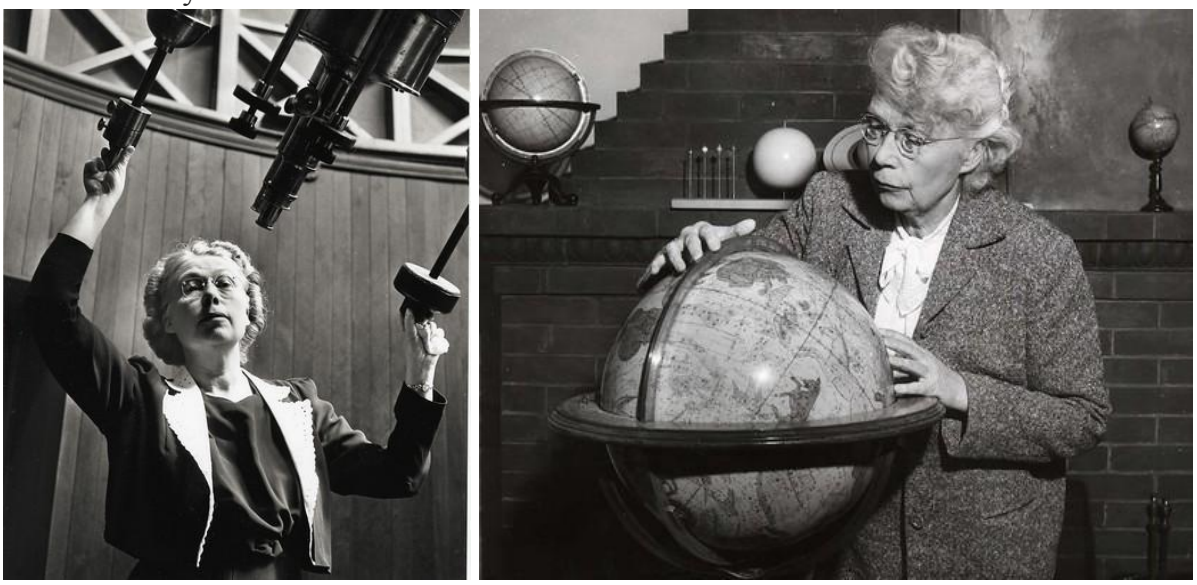
Shane Archives, which were renamed in her honor in 1983, preserve an invaluable record of Lick Observatory.[34]



Maud Worcester Makemson (Photo: Vassar College Encyclopedia)

Maud Worcester (Makemson) (1891-1977)

Maud Worcester followed a circuitous route from teaching to journalism to the field of astronomy. After attending Girls Latin School in Boston, she studied Greek and Latin for one year at Radcliffe College. Following a brief stint of teaching, she moved to Pasadena, California with her family. Soon afterwards Maud Worcester married Thomas Makemson and had three children. After divorcing her husband in 1919, she got a job in Arizona as a journalist. There she witnessed the great aurora in May 1921, which sparked her interest in astronomy. Showing unshakeable determination, Makemson enrolled in correspondence courses in trigonometry and astronomy from UCLA and then took science classes in summer school. Finally she gained admission to UCLA and earned a bachelor's degree in 1925 at the age of thirty-four. Six years later she received her PhD from Berkeley in astronomy in 1930.

Makemson was appointed to the Vassar College faculty as an assistant astronomy professor in 1932 and was promoted to full professor in 1944. In 1936, she succeeded Caroline Furness as the fourth woman to direct the Vassar Observatory after Maria Mitchell, a somewhat controversial appointment because she was viewed as a "mature" assistant professor. She directed the observatory until 1957. Professor Makemson taught Vera Rubin, Vassar class of 1948, who became an eminent astronomer and made critical discoveries about dark matter. Rubin said of her professor "She was a very thorough teacher, demanding high quality in return." With her students, Makemson computed the orbits of twelve minor planets, and named one "Maria Mitchell" and another "Vassar."

Maud Makemson's research and publications about primitive astronomy and mythology reflect her broad interests in languages and anthropology. During sabbatical leaves from Vassar and while on a Guggenheim Fellowship, she conducted research in Mexico and published *The*

[34] https://www.ucolick.org/main/explore/archive.html

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Astronomical Tables of the Maya (1943). Then in 1954 she wrote an article "Astronomy in Primitive Religion" in which she discussed the worship of celestial bodies in Mesopotamia, China, Egypt, Greece, and Rome.[35] She spent a year in Japan and Punjab on a Fulbright Teaching Fellowship in 1953-54.

After retiring from Vassar in 1957 Makemson taught at UCLA and co-authored *Introduction to Astrodynamics*, the first text of its kind,[36] with Robert Baker of UCLA. Never ceasing, Makemson's final contributions focused on space research. She moved to Applied Research Laboratories of General Dynamics in Texas as a consultant to NASA on lunar exploration in 1964-65. She found a way to enable astronauts to determine their positions on the moon while they had no access to radar or radio. When she began her research on "Determination of Selenographic Positions,"[37] she did not realize its usefulness. "When I developed an approximate method for determining selenographic latitude and longitude from star altitudes observed from the Moon's surface, the practical need for such a method seemed most remote. Now, in 1970, a method for finding accurate positions on the lunar surface is… an essential factor in every selenodetic survey."

Lois Tripp Slocum

Lois Tripp Slocum (1899-1951)

Lois Slocum was born in New Bedford, Massachusetts to a family of seafaring ancestors. She was the niece of Frederick Slocum, a professor of astronomy at Brown University, whom she knew and visited several times as a student. Slocum graduated from Smith College in 1921 in astronomy and earned a master's degree there in 1924. In the graduate program at Berkeley, Slocum studied the Milky Way galaxy and dark nebulae. She received her doctorate in astronomy in 1930, supervised by Professor Robert J. Trumpler. Her thesis was a study of the colors of faint stars in a section of the Milky Way and she was strongly interested in teaching astronomy. She taught briefly at Wellesley but spent a full decade at Smith, where she was an instructor and assistant professor of astronomy from 1932-43. While teaching at Smith, Slocum continued to publish in astronomical journals. During War II, she contributed to the war effort at

[35] Maud M. Makemson. "Astronomy in Primitive Religion: Journal of Bible and Religion," Vol. 22, 3.July 1954.
[36] Robert M.L. Baker and Maud W. Makemson. *Introduction to Astrodynamics*. New York: Academic Press, 1960.
[37] Maud W. Makemson. "Determination of Selenographic Positions." T*he Moon*, Vol.2, 3, February 1971.

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Harvard's secret Radio Research Laboratory. In 1944 she was appointed professor of astronomy at Wilson College, a college for women in Chambersburg, Pennsylvania, where she remained for the rest of her career. Slocum was an active member of the American Association of Variable Star Observers. Her career was cut short by her early death at the age of 52. Her family established an annual Lois T. Slocum Memorial Lecture at Wilson College. Astronomer Bart Bok (husband of Berkeley alumna Priscilla Fairfield Bok) gave the first lecture in 1952 on "The Depths of the Milky Way." Bok said "She was one of the first to demonstrate both the potential power of the color attack and the great difficulties that lay ahead."[38] Bok praised the significance of Lois Slocum's research and dedication to teaching until the very end of her life and said that she would have been pleased by his chosen topic, the subject of her own research.

Charlotte Moore Sitterly (Photo: AIP Emilio Segrè Visual Archives, Gift of Michael A. Duncan)

Charlotte Emma Moore (Sitterly) (1898–1990)

Charlotte Moore earned an Astronomy PhD from Berkeley in 1931. Although Berkeley is proud to claim her, Moore spent most of her career at Princeton. Following graduation from Swarthmore College in 1920 as a math major, with no prior experience Moore was employed as a *computer* to process astronomical data. Moore's job was to calculate the positions of celestial bodies for the preeminent astronomer Henry Norris Russell (1857-1957) in the Princeton Astronomical Observatory. In 1925 Moore started a study of the solar spectrum. She left to spend two years in California working at the Mt. Wilson telescope as a computer but found she had been given more responsibility at Princeton with Russell. She recalled "…at that time there were not too many chances for any woman, no more chance there for a woman than there was at Princeton and I felt that I had more opportunity to get into general astrophysics with Dr. Russell than I did being channeled out there [in California] as a computer. There was little opportunity to broaden or advance."[39] Moore attended graduate lectures at Princeton, but she was unable to

[38]Bart J. Bok. "The depths of the Milky Way." *Popular Astronomy,* Vol. 59, 501 ff.

[39] Interview of Charlotte Moore Sitterly by David DeVorkin on 1978 June 15, Niels Bohr Library & Archives, American Institute of Physics, College Park, MD.
www.aip.org/history-programs/niels-bohr-library/oral-histories/4784

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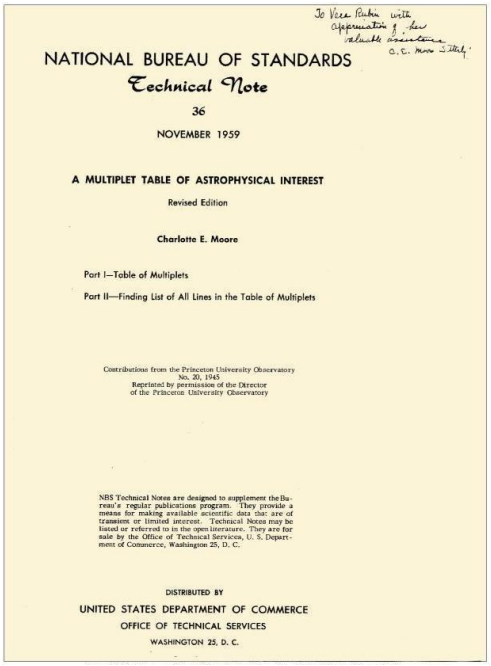
enroll for graduate study at Princeton University because women were not yet admitted at that time. “Princeton wouldn’t have anything to do with women under any circumstances. I could get no credit there whatever. There was no way.” [40] While Russell was on a two-year trip to Europe, Moore came west to Berkeley where she won a Lick Fellowship at the Observatory. While working on her PhD, she continued researching spectroscopy and collected and analyzed data about the spectra of chemical elements and molecules. She completed her PhD in two years, in1931, with a thesis on “Atomic Lines in Sun-Spot Spectra.”

After obtaining her degree Moore returned to Princeton to continue research with Russell until his death in 1957. In 1937, Moore presented a paper at the American Astronomical Society in 1937 announcing her discovery of three new elements in the sun. That year she was given the Annie Jump Cannon Award for contributions to astronomy by a woman PhD within five years of her degree.[41] After an evening of stargazing, she accepted a proposal of marriage to a Princeton colleague, astronomer Bancroft Sitterly. Moore continued to publish under her maiden name; she co-authored an influential book *The Masses of the Stars*[42] with Russell in 1940. She spent the rest of her career as head of spectroscopy at the National Bureau of Standards in Washington, D.C. Sitterly led a new compilation of atomic energy levels, resulting in *Atomic Energy Levels*, (1949), which included data for 485 atomic species “in a uniform clear format with standardized notation. One of her lasting contributions was the compilation of tables of atomic spectra, an enduring contribution to astronomy. “The convenient availability of these data during the past three to four decades has had a large influence on research in atomic, optical, laser and plasma physics chemistry and anatomy……. Sitterly was called a ‘one-woman world data center for spectroscopic and astrophysical data.’ ”[43]


NATIONAL BUREAU OF STANDARDS
Technical Note
36
NOVEMBER 1959
A MULTIPLET TABLE OF ASTROPHYSICAL INTEREST
Revised Edition
Charlotte E. Moore
Part I—Table of Multiplets
Part II—Finding List of All Lines in the Table of Multiplets
Contributions from the Princeton University Observatory
No. 20, 1945
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She described her work modestly in a 1961 interview: “It isn’t glamorous, but the work itself carries you along on its own interest.” A bibliography of Sitterly’s publications illustrates her prolific scholarship. [44]Among her numerous prestigious honors, Charlotte Sitterly was awarded the Bruce Medal for Lifetime Contributions to Astronomy by the Astronomical Society of the Pacific in 1990. The Moore-Sitterly Asteroid 2110 discovered at the Indiana Observatory was named for her in 1962.[45]

[40] DeVorkin, AIP. Ibid.
[41] The Annie Jump Cannon Award was donated by Annie Jump Cannon of the Harvard Observatory.
[42] H.N.Russell, H. N. and C. E. Moore. *The Masses of the Stars*. Chicago: University of Chicago Press, 1940.
[43] Necrology, Standards Alumni Assoc. Newsletter, vol. 90, no. 2, 8.
[44] Sitterly bibliography: http://www.phys-astro.sonoma.edu/brucemedalists/sitterly/SitterlyRefs.html
[45] https://ssd.jpl.nasa.gov/sbdb.cgi?sstr=2110

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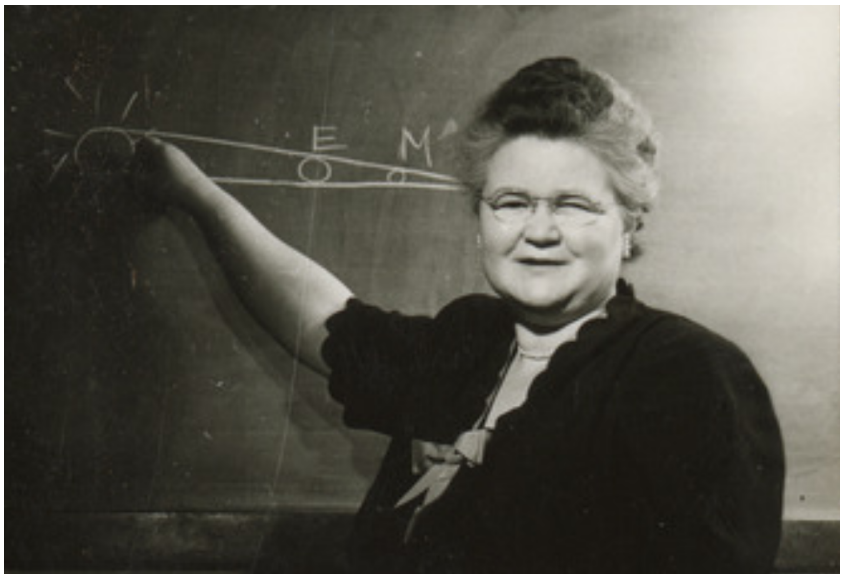

Phyllis Hayford Hutchings (Photo: Whitman College Archive)

Phyllis Hayford (Hutchings) (1904-1965)

Phyllis Hayford graduated Phi Beta Kappa from Northwestern University in civil engineering, where her father was the dean. She enrolled at Berkeley and earned the PhD in 1932. She conducted research at Lick Observatory for six years through 1937, according to the observatory logs.[46] She married William Lawrence Hutchings, a 1935 Berkeley PhD graduate in math. They both were hired at Rollins College in Winter Park, Florida, where she taught astronomy and her husband taught math. An article in the college newspaper reports a speech she gave about observatories of the West in 1937.[47] The couple was then appointed in the astronomy and math departments respectively at Whitman College, in Walla Walla, Washington. Phyllis Hutchings was listed in "American Men of Science" in 1949, with research interests of galactic rotation, orbit computation, asteroids and comets. Unexpectedly she died at the age of 61. Hutchings's dedication to teaching was praised by Whitman's president Louis B. Perry who called her "one of those rare individuals with tremendous loyalty to her institution and above all to her students. Without question she was among the most beloved members of the faculty at Whitman College and will leave a gap in the hearts of her colleagues and students which will never be filled."[48]

[46] Phyllis Hayford. Reduction Book, No. 4 , *Measuring Book No. 2, Eros Plates.*, 9 November 1934–14 May 1937 http://collections.ucolick.org/archives_on_line/about.html

[47] Sandspur, Vol. 42 No. 24, April 7, 1937, Rollins College.

[48] Walla Walla Union-Bulletin, July, 1965.

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Katherine Prescott "Co-ed Comet Calculator" (Photo: *Oakland Tribune,* December 1927)

Katherine Prescott (Kaster) (1901-unknown)

The daughter of a physician, Katherine Prescott was raised in a prosperous family in Boston. She earned an undergraduate degree in astronomy and physics from Berkeley in 1923. On the basis of undergraduate research she was elected to Sigma Xi, a scientific research honors society. As a graduate student in astronomy, Prescott was named a Fellow at Lick Observatory. The Oakland Tribune published an article "A Co-ed Comet Calculator" about Prescott and a fellow student who plotted the path of an oncoming comet in 1927. Prescott wrote her dissertation "On the motions of perijove of the fifth satellite of Jupiter" and earned the doctorate in 1933. While in graduate school she married Howard B. Kaster, a Berkeley alumnus of the class of 1922 with a BA in astronomy. As a graduate student, Kaster wrote at least one research paper with her husband, Howard Kaster: "The Orbit of a Comet a 1925" published by the Astronomical Society of the Pacific.[49] Claiming cruelty, Katherine Kaster sued for divorce in 1934 after six years of marriage. The Oakland Tribune reported that Howard Kaster "began to complain about her cooking."[50] Katherine Kaster continued to publish in astronomy journals through the 1940s. Lick Observatory, where she was employed as a Research Fellow in Astronomy, records her activity there from 1924 -1937. Scant biographical information is available about Katherine Prescott's professional life after 1940. From a very promising early career, she seems to have disappeared from astronomy. In 1942, she published a history of two coastal islands in Maine, which presumably were associated with the Prescott family: *Cousins and Littlejohn's Islands, 1645-1893.*

[49] Howard B. Kaster and Katherine Prescott. "The Orbit of a Comet a 1925". Astronomical Society of the Pacific, Vol. 37. No 217, June 1925, 145-147.

[50] Oakland Tribune, At some point in the 1930s, Howard Kaster was a Naval officer and faculty member at the College of San Mateo, where he established a scholarship for students in the sciences.

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Group at Leuschner Observatory, Berkeley Campus: First row: Strong, John D. Shea, Bing C. Wong, Poblanz; second row: H. Thiele Arthur Williams, Muriel Wilkinson, Katherine Prescott, Mary Lea Shane, S. Einarsson, Joseph Pearce, W.F. Meyer, Tom Buck; third row: Charles Donald Shane, Howard Kaster, R.T. Crawford, E.W. Brown, Armin O. Leuschner, R. Scroberetti, V.F Lenzen (Photo: Astronomy Dept, UC Berkeley)

Dorothy Davis Locanthi

Dorothy N. Davis (Locanthi) (1913-1999)

Born in East St. Louis, Missouri, Dorothy Davis was a precocious student. In high school she stood at 6'4" and broke a world track record for the standing broad jump. After finishing high school in three years, she entered Vassar in 1929 and studied both physics and astronomy. Two of

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her Vassar professors were Caroline Furness, mentor to Phoebe Waterman, and alumna Maud Makemson. Davis was admitted to the graduate program in astronomy at UC Berkeley but could not afford to attend. Fortunately Mills College in Oakland offered her a one-year teaching fellowship and the chance to earn a master's degree. While teaching at Mills, she did research at the Lick Observatory, guided by Berkeley professor Donald Shane. The next year Davis received an assistantship from Berkeley and entered graduate school. She wrote her thesis on the spectrum of Antares and became an expert on molecular spectra. On completion of her PhD in 1937, Davis taught briefly between 1937-1939 at Vassar and at Smith. When she won an American Association of University Women Postdoctoral Fellowship, she was able to return to her real interest, research, at Mount Wilson Observatory. In 1940 she was invited to Princeton to assist astronomer Henry Norris Russell, Charlotte Sitterly' boss. During World War II, Davis contributed to the war effort at Caltech working on weapons programs and a rocket project. In 1943 she married a Caltech student, Bart Locanthi, who was assigned to the same project. After the war, she took a job at Beckman Instruments to help support her husband through school. When her first child was born in 1945, Locanthi dropped out for two years. With the birth of two more children, she stayed home until 1962. Locanthi held a series of half-time jobs at Caltech and Jet Propulsion Laboratory. After 1962 she never returned to full-time research but continued working, attending scientific meetings and presenting papers.

Patty Stahr Carpenter (Photo: National Radio Astronomy Observatory)

Martha "Patty" Stahr (Carpenter) (1920-2013)

Born in Bethlehem, PA, Martha "Patty" Stahr received a BA from Wellesley College in 1941, majoring in astronomy. Her lifetime interest in astronomy started through a junior high school science club. "I yearned for a telescope of my own," she recalled. While at Wellesley she built her own telescope with help from the Amateur Telescope Makers of Boston. Stahr earned an MS in 1943 with a master's thesis on the "A Method of Calculating Curves of Growth" and a PhD in astronomy from Berkeley in 1946. Advised by Robert J. Trumpler, she wrote a

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dissertation entitled "A Study of the Radial Velocities of Faint F and G Starts near the North Galactic Pole."
Stahr made observations and measured radial velocities of F and G stars near the North Galactic Pole in an effort to investigate the gravitational force within the Milky Way Galaxy. Stahr also found and measured tilting of the central plane of the galaxy from pioneering radio-wave observations. She was active in the American Association of Variable Star Observers (AAVSO), and contributed 396 visual observations to the AAVSO between 1940 and 1950.

AAVSO, 1952 (Photo: AAVSO)

In graduate school Stahr spent 1944–1945 at Lick Observatory, where she used the spectrograph on the 36-inch refracting telescope. She recalled that students would ordinarily never have been allowed to use this instrument, but since it was during war years, "…most of the astronomers had left. There was a discussion as to whether a woman could handle the big telescope, [but] I just went up there. The man was there doing all he could to handle it, and it wasn't before long that I was doing it with him, so they were very glad that the telescope was kept in use, because it was more than one person could handle."[51]
Carpenter's first job was teaching astronomy at Wellesley. She required her class in Practical Astronomy to contribute data to the AAVSO. In 1950 she became the first woman faculty member appointed in the College of Arts and Sciences at Cornell University. For several of her 18 years at Cornell, Carpenter was one of only two-full time astronomy professors. She collaborated with the School of Electrical Engineering project to observe radio waves from celestial objects, such as the sun and galactic center. Cornell established the first research program in radio astronomy at an American university. Carpenter was advisor to astronomer Vera Rubin on her master's thesis. In 1951 Martha Stahr married Jesse Thomas Carpenter, a labor economist who was 21 years older than she. The couple had two daughters.
In the 1950s and 60s Carpenter published the first-ever comprehensive bibliographies of literature in radio astronomy from all over the world, at a time when such information was not well known. In 1968 she and her husband moved to the University of Virginia to be closer to his family. At UVa she began as a part-time instructor and retired in1985 as associate professor of astronomy. Her research encompassed many areas including variable stars, extraterrestrial radio

[51] The quotes and reminiscences of Patty Stahr are drawn from: Kristina Larsen. "Reminiscences on the Career of Martha Stahr Carpenter: Between a Rock and (Several) Hard Places." *JAAVSO Volume 40, 2012, 51*

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noise and galactic structure. She served the AAVSO as president for several terms during a turbulent time for the organization, which had meant a great deal to her since college.

Helen Pillans (Photo: Ted Streshinksy)

Helen Pillans (1909-1984)

Helen Pillans was a visionary scientist who foresaw the importance of computer science for college women and acted on that conviction. She and her mother moved to Hawaii after her father died when she was eight, and Helen became fascinated by the stars in the night sky. At age 13, Pillans asked her mother what the sun was, and was shocked to find that she did not know. She attended the University High School in Oakland and graduated from the Anna Head School for Girls. She earned a bachelor's in 1932 and a master's degree in astronomy in 1933 from the University of Chicago. As was typical for women with advanced degrees in science, Pillans found positions at three colleges for women, Hollins, Mount Holyoke and Mills College. At Hollins College, she was an instructor in physics and astronomy from 1936-42. Mount Holyoke, where she taught astronomy from 1942-1947, had a strong astronomy program led by women, thanks to the Williston Observatory built in 1881. Thirteen years after earning her master's degree, Pillans returned to California to enter the astronomy PhD program at Berkeley in 1947 and was awarded her doctorate in 1952. While a Berkeley graduate student, Pillans published articles in 1944, 1947, and 1947 on "Occultation of Stars by the Moon" with Alice H. Farnsworth, her Mount Holyoke faculty colleague, who directed the Williston Observatory.[52]

Helen Pillans spent the rest of her career at Mills College from 1957 until her retirement in1974. At Mills Pillans taught physics and mathematics during the academic year, and astronomy during January term. She spent seven summers as Visiting Associate Professor of Astronomy at UC Berkeley from 1964-1971. Despite a full teaching load, Pillans continued to write scientific papers through the 1950s for the Astrophysical Journal and Publications of the Astronomical Society of the Pacific. She rose to full professor at Mills, where she was known for her innovative views on education, brilliant teaching, and close rapport with students. In 1959 Pillans

[52] Helen Pillans and Alice Farnsworth. "Occultation of Stars by the Moon" Astronomical Journal, 51, 58.

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wrote *Elementary Astronomy* co-authored with acclaimed Berkeley astronomy Professor Otto Struve and astronomer Beverly Lynds, a 1955 Berkeley PhD.[53] An influential Russian astronomer, Otto Struve was chair of Berkeley's Astronomy Department from 1950-1959 and director of the Leuschner Observatory. Their book, intended as general background in astronomy for students studying physical science who lacked mathematical training, was deemed both easy to read and very thorough.

"Computers are revolutionizing our whole society and changing our approach to science."

Helen Pillans was prescient in realizing the power of computers. She used one for her dissertation research. In a 1965 article, "A Computer at Mills College?"[54] Pillans explains to Mills alumnae in the evolution of computing in higher education since 1950 and its ubiquitous applications. Calling computers "tools to amplify our intellect," Pillans introduced computing into both science and math courses but notably also fine arts. She was instrumental in obtaining a National Science Foundation grant in 1968 for Mills to join the regional educational computing network at Stanford. Lenore Blum, Mills Professor Emerita who created the Mathematics and Computer Science Department at Mills in 1973, credits Helen Pillans' bold vision for the development of computer science at Mills. "Helen was ahead of her times in many ways and in particular in realizing the importance of computers, not just in science but in the arts and the liberal arts. Because of the foundation she laid down at Mills, I was able to envision and develop a Computer Science Department at Mills when I arrived there in 1973. This was the first such department at any women's college in the country, probably anywhere. Helen was so supportive of me and enthusiastic about this direction, I could not have done it without her."[55] Mills College Computer Center is named for Helen Pillans. She was enthusiastic about engaging the public in astronomy and lectured widely to all kinds of audiences. Pillans maintained memberships in the American Association of Variable Star Observers, Sigma Xi, and the Astronomical Society of the Pacific. Always looking ahead, Helen Pillans supported the race to reach the moon, which she predicted. "Someday," she said in 1964, "I certainly would like to go to the moon." [56]

[53] Helen Pillans, (with Otto Struve and Beverly Lynds). *Elementary Astronomy*. New York: Oxford University Press, 1959 Professor Beverly Lynds earned a PhD in astronomy at Berkeley in 1955. She taught at University of Arizona and worked at Kitt Peak Observatory.
[54] Pillans. "A Computer at Mills College?" Mills College Magazine, Autumn 1965, 15-22.
[55] Personal Communication, Lenore Blum, April 2021.
[56] "Reaching for the Moon," San Francisco News Call Bulletin. Monday, April 13, 1964, 19.

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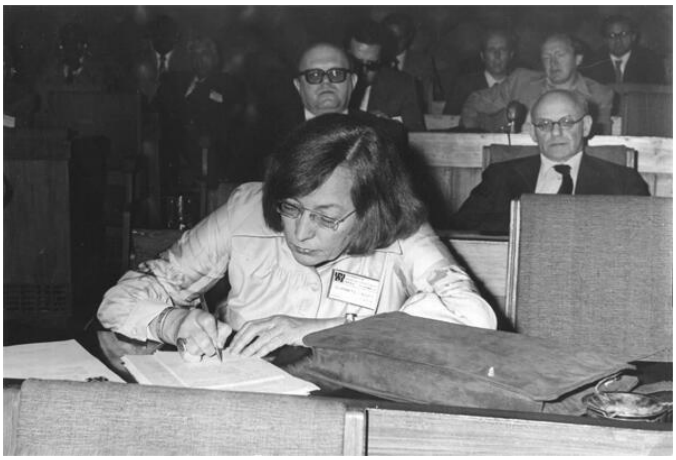

Elizabeth Leonard Scott (Photo: Berkeley Statistics Department)

Elizabeth Leonard Scott (1917–1988)

During the late 1940s and early 1950s Berkeley granted doctoral degrees in astronomy and mathematics to several women whose studies were significantly interrupted by World War II. Among them were Elizabeth Leonard Scott, Evelyn Fix, and Julia Robinson. Elizabeth Scott, known as Betty, grew up in Oakland and graduated from Berkeley in 1939 with a bachelor's degree in astronomy. Her family moved to Berkeley specifically so that their children would attend UC Berkeley, with free tuition. At the age of twenty-two Scott wrote her first research publication, about comets. Scott was recruited by Professor Jersey Neyman to help with the war effort in his Statistics Lab. Scott went on to earn a PhD in astronomy from Berkeley in 1949. Advised by Robert Trumpler, she wrote a thesis in two parts. Part I was on "Contribution to the Problem of Selective Identifiability of Spectroscopic Binaries" and Part II was on "Note on Consistent Estimates of the Linear Structural Relation Between Two Variables."

In 2017 a former student, Professor Amanda Golbeck (biostatistics), wrote an extensive biography of Scott: *Equivalence: Elizbeth L. Scott at Berkeley*.[57] Scott's maternal aunt astronomer Phoebe Waterman Haas (profiled above) was undoubtedly an influence. Thirty-five years older than Scott, Haas saw her niece periodically at summertime family gatherings near Annapolis, Maryland. Scott was aware that Waterman was a pioneer whose marriage deterred a professional career in astronomy but who had resolutely continued her work as a variable-star observer. Scott was reluctant to credit her aunt directly: "It is very hard for me to say how much she influenced my going into Astronomy. Certainly, indirectly but not much directly."[58] Golbeck questions why Scott may not have wished to acknowledge Waterman's influence. Scott acknowledged that she sometimes discussed astronomy with her aunt, but not until she was studying astronomy as a Berkeley undergraduate: "My mother's oldest sister had a doctorate in astronomy, but I knew her only as a friendly aunt whose children we played with. She was no longer active in astronomy.... We never talked about astronomy before I was in college, but I did know that astronomy existed and that there were women astronomers."

[57] Amanda L. Golbeck, *Equivalence: Elizabeth L. Scott at Berkeley* Boca Raton, FL: Chapman Hall, 2017. Golbeck drew on 120 boxes of Scott's papers which are stored by UC's Bancroft Library, but to date are not accessible to scholars because they have never been catalogued.

[58] Golbeck, *Equivalence* 88-91.

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Scott realized that because of discrimination, since women were barred from the use of certain large telescopes, she would have more research opportunities as a mathematician and statistician than as an astronomer. She explained her reasoning: "Well, it is not too often that you can actually put your finger on a discrimination, and you know that you really can prove that it was there. There was no secret about it. Women were not allowed to use the big telescopes at Mt. Wilson, the 60-inch and 100-inch. Women were not on the staff. There are no women on the staff at the Mount Wilson and Palomar Observatories. ... It was just forbidden. That went on for many years."[59] She was appointed assistant professor of mathematics in 1951 and left to join the newly formed Statistics Department at Berkeley in 1955-56. She served as chair of Statistics from 1968-73. However, Scott never abandoned her interest in astronomy, and between 1949-1964 she published over 30 additional papers in astronomy. Scott applied statistics to solve research questions in astronomy.

In 1957, she identified a bias in the observation of galaxy clusters, realizing that distant clusters could only be found if they contained brighter-than-normal galaxies, as well as a large number of galaxies. She submitted a formula to correct for what became known as *the Scott effect*. Scott's earlier papers focused on the use of statistical tools to answer important questions in that field, followed by a shift to work using astronomy as the motivation for and application of statistical ideas. "This series of papers centered on the premise that the universe and its elements were products of random processes. Later papers extended the ideas about distribution of galaxies to more than two regions in space, regions that may or may not be disjoint, as well as extensions to many other statistical properties."[60]

Scott also worked in other areas of statistics. She wrote over 20 papers on cloud seeding, analyzing weather modification research particularly rain stimulation in the 1960s and 1970s. Another focus was the relationship of ozone depletion and skin cancer, research undertaken with an interdisciplinary team.

In the 1970s, Elizabeth Scott carried out rigorous studies on salary disparities between men and women faculty at UC Berkeley and in the nation. With anthropologist Elizabeth Colson, Scott co-chaired a subcommittee of the Berkeley Academic Senate, which published a comprehensive seventy-eight-page study of the status of women in academia at UC Berkeley.[61] The report examined not only salary and benefits but also hiring, promotion and tenure, research opportunities and committee appointments. "Considerable disparities in treatment were documented and Scott promptly turned her attention to finding remedies. What Scott was doing here was unique. While most faculty women spent their time simply turning out evidence that they were paid less than their male counterparts, Scott was collaborating in studies, employing multiple regressions that soon were used by universities in making salary adjustments and came to be widely accepted as evidence in lawsuits. Her work on this topic earned Scott a reputation as

[59] An Interview with Elizabeth Scott, "Oral History, the Women's Faculty Club of the University of California, Berkeley, 1919–1982, Regional Oral History Office, Bancroft Library, University of California, Berkeley, 1983, 149.
[60] David Blackwell, Elizabeth Colson, Susan Ervin-Tripp, Lucien Le Cam, Erich Lehmann, Laura Nader. In Memoriam. Elizabeth Scott. 1988
[61] E. Scott, S. Ervin-Tripp, and E. Colson, *Report of the Subcommittee on the Status of Academic Women on the Berkeley Campus* (Berkeley: University of California, Berkeley, May 1970).

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a pioneer in applying statistical methods to research on the status of academic women."[62] The Elizabeth L. Scott Award was established in 1992 to recognize Scott's lifelong efforts to advance the careers of women in academia. Scott's legacy at Berkeley lives on: Berkeley Statistics Professor Bin Yu won the Scott Award in 2018, as did her biographer Amanda Golbeck in 2012.[63]

Conclusion

In the early decades of the twentieth century, astronomy was field distinguished by a gendered division of labor. Virtually all women astronomers began their professional careers as computers. Until they proved themselves and acquired advanced training, even the successful astronomers began by interpreting the data of male astronomers. Those women doing observational astronomy faced such challenges as working through long nights in the unheated dome at Lick Observatory. Often students were required to haul heavy equipment. Life on Mount Hamilton was isolated, remote from the Berkeley campus and the civilization of San Jose.

Yet isolation had its benefits. It's hard to overstate the positive environment of the Lick Observatory community as reported by former students like Mary Shane. Encouraging mentors such as Professors Campbell, Leuschner, Shane, and Trumpler guided the Berkeley women to successful completion of their doctorates. Most returned in later years in summer or on leaves from their teaching posts to continue research on Mount Hamilton, and some continued to publish joint research.

The career choices made by the women illustrate the available options in their era: independent research as a citizen scientist (Phoebe Waterman Haas); switching fields from astronomy to math (Sophia Levy Macdonald) or to statistics (Elizabeth Scott); close collaboration with a male partner with indistinguishable joint achievements (Priscilla Fairfield Bok); close collaboration with but secondary status to that of a prominent male astronomer (Charlotte Moore Sitterly); teaching in women's colleges (Priscilla Fairfield Bok, Maud Worcester Mackemson, Lois Tripp Slocum, and Helen Pillans); teaching at a coeducational university but advancing slowly (Jessica Young Stephens, Phyllis Rayford Hutchings); employment as a scientist in industry (Estelle Glancy, Dorothy Locanthi, Makemson); government (Charlotte Sitterly, Dorothy Locanthi); active partnership with an astronomer spouse (Mary Heger Shane); or dropping out (Edith Cummings Taylor, Katherine Prescott Kaster). Although Taylor and Kaster appear to have lost touch with the field, but since there is no information available, perhaps they did continue in some way.

The existence of the AAVSO was unique in providing astronomers an ongoing opportunity to contribute their own observational data on variable stars and to be recognized, regardless of employment status. Further, the early graduates all contributed significantly to the war effort in the 1940s. Despite prevailing attitudes toward women in astronomy with the limiting constraints, all but two of the Berkeley women graduates persisted. They led rewarding and productive

[62] Francesca Webb and Edmund Robertson, "Elizabeth Leonard Scott," School of Mathematics and Statistics, University of St. Andrews, Scotland, August 2007, http://www-groups.dcs.st- and.ac.uk/history/Biographies/Scott_Elizabeth.html.
[63] https://community.amstat.org/copss/awards/scott

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professional lives and contributed meaningfully to teaching and research in astronomy. Whatever path they followed, the achievements of the early Berkeley women astronomers and the satisfaction they took in their work are remarkable and worthy of celebration in this 150th year since the admission of women to the University of California at Berkeley. .

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