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Chapter 1

Beginnings

In France, Dorothea Klumpke (1861–1942) earned her Docteur-ès-Sciences at the University of Paris in mathematical astronomy in 1893, after completing her thesis, "L'etude des Anneaux de Saturne" (A study of the rings of Saturn), thereby becoming the first woman to achieve the academic distinction of earning an advanced degree for work done in astronomy. She then began her distinguished career as the director of the Bureau des Measures at Observatoire de Paris, leading the effort there to produce a section of the great photographic star chart known as the *Carte du Ciel*. In 1901, she married astronomer Isaac Roberts and moved with him to England. After his death in 1904, Klumpke Roberts returned to Observatoire de Paris, where she continued to carry out astronomical research, and in 1929 published *The Isaac Roberts Atlas of 52 Regions, a Guide to William Herschel's Fields of Nebulosity*. In 1934, she was elected Chevalier de la Légion d'Honneur.

Professional successes like hers, built on her own credentials, accomplishments, and intellectual merits, were rare for women before 1900. Instead, most of the few women who in previous centuries had any role in astronomy typically gained access through their husbands, brothers, or fathers.

More than two centuries earlier, in Danzig (now Gdańsk), Poland, in 1663, sixteen-year-old Catherina Elisabetha Koopman (1647–93) married fifty-two-year-old astronomer Johannes Hevelius, which gave her access to his observatory, Stellaburgum, where she became his assistant. In 1687, as Elisabetha Hevelius, she would publish the catalogue she and

Johannes had worked on for decades, the *Catalogus Stellarum Fixarum*, which included the positions of 1,564 stars, including 600 newly identified stars and a dozen newly named constellations.

Beginning in 1774, in Bath, England, Caroline Lucretia Herschel (1750–1848) assisted her older brother William with his observational work, cataloging thousands of previously unknown star clusters and nebulae, and learning to make her own observations and astronomical calculations. On her own, she discovered eight comets and the galaxy NGC 205. But her most important work was done in helping her brother put together the *Catalogue of One Thousand New Nebulae and Clusters of Stars*, which was first published in 1786 with William as sole author. They added another 1,000 objects to this catalogue in a 1789 paper, and 500 more in a third version published in 1802, each time with William as the only author credited. Later, she helped her nephew John Herschel expand the inventory to more than 5,000 objects in his 1825 *Catalogue of Nebulae and Clusters of Stars*. For her efforts on this project, in 1828 the Astronomical Society of London (which in 1831 would become the Royal Astronomical Society) honored her with their Gold Medal and then, in 1835, elected her as an honorary member (according to the organization's by-laws at that time, women were ineligible for election as regular members). Her career, important and limited as it was, was only possible because her brother and nephew needed her help.

Mary Fairfax Somerville (1780–1872), known in her time as the "Queen of Science," was also elected as an honorary member of the Royal Astronomical Society in 1835. Somerville was an exception to the rule that women who contributed in a significant way to astronomy before 1900 did so because they were the wife, sister, or daughter of an astronomer. Her second husband, William (a surgeon), encouraged her, but she forged her professional career independent of his. In 1826, Somerville's "The Magnetic Properties of the Violet Rays of the Solar Spectrum" was the first research article written by a woman published in the *Philosophical Transactions of the Royal Society*. She would later cement her reputation as a popularizer of science, writing several books, including *The Mechanism of the Heavens* in 1831 and *On the Connexion of the Physical Sciences* in 1834.

A half century later, Margaret Lindsay Huggins (1848–1915) was instrumental in furthering the successful career of her husband, William. Beginning in the late 1870s, she was a participant with him in photographic and spectroscopic research, including his studies of the Orion Nebula and the planets, and conducted some of her own research at their private observatory in London, England. With William, she wrote *Atlas of Representative Stellar Spectra*, published in 1899, and was elected (an honorary member) to the Royal Astronomical Society in 1903.

Also in the late nineteenth century, Mary Proctor (1862–1957) learned to help her father, the famous English astronomer and popular science writer Richard Proctor, with his manuscripts and in founding and publishing the journal *Knowledge*, which led to her own career lecturing about astronomy and writing about astronomy for children. She was elected as a member of the British Astronomical Association (BAA) in 1897 and to the Royal Astronomical Society (a society with, relatively, more professionals than the BAA) in 1916 as one of its first female Fellows.

Another British woman of this era, Mary Evershed (1867–1949), worked closely with her husband, John, who directed the Observatory at Kodaikanal in India. Her observations of solar prominences were published in a single-author paper in the *Monthly Notices of the Royal Astronomical Society* in 1913.

The only other women named honorary members of the Royal Astronomical Society prior to the change in the rules in 1915 that permitted women to be elected as ordinary members were Anne Sheepshanks (1789–1876), whose claim to fame was donating significant sums of money to the University of Cambridge to promote astronomical research, Agnes Mary Clerke (1842–1907), who was considered Somerville's successor as a well-received popularizer and historian of astronomy, and two human computers at the Harvard College Observatory, Williamina Fleming (1857–1911) and Annie Jump Cannon (1863–1941), who made measurements and computed the positions, brightnesses, and spectral types of stars whose images were found on photographic glass plates obtained by (male) Observatory astronomers.

Fleming began her astronomical work because she was in the right place at the right time—in 1881, she was the housekeeper for Harvard

College Observatory director Edward C. Pickering when he invited her to start working at the Observatory as a computer. She assigned spectral types to, and calculated positions and brightnesses for, most of the nearly 10,000 stars included in the first *Draper Catalogue of Stellar Spectra*, published in 1890. She continued her work as a computer until her death in 1911.

Cannon, who worked at the Observatory from 1896 until 1940, is perhaps the most famous of the Harvard College Observatory computers. She put her stamp on modern astronomy through her work classifying the spectra of more than 225,000 stars and reinventing the stellar classification system, which was formally adopted for use by the international astronomy community in 1922. Her system of stellar spectral classes, used in the nine-volume expansion of the *Henry Draper Catalogue* published in the years from 1918 to 1924, is still in use today. Cannon, who in 1938 was appointed as the William C. Bond Astronomer and Curator of Astronomical Photographs at the Observatory, was the first woman to receive an honorary doctorate from the University of Oxford.

In 1888, Antonia Maury (1866–1952) also became one of Pickering's famous computers (she continued to work at the Harvard College Observatory until 1933), in large part because she had a family connection: her aunt Anna Palmer Draper (1839–1914), the widow of Henry Draper, had donated the money to the Observatory that supported the work of producing the *Draper Catalogue* and the *Henry Draper Catalogue*. Maury discovered that some stars had narrow and others had broad spectral lines. And though her boss was not interested in this way of classifying stars on the basis of the widths of their spectral lines, others were. Maury's discovery has been used by astronomers for more than a century to help distinguish evolved stars with extended envelopes (giants, which have narrow lines) from stars still living on hydrogen fusion in their cores (dwarfs, or main-sequence stars, which have broad lines).

Henrietta Swan Leavitt (1868–1921), who worked as another of Pickering's computers from 1902 until 1921, made perhaps the most important astronomical discovery of her time when in the 1900s she identified a few handfuls of stars known as Cepheid variable stars—stars that cycle

from bright to faint and then to bright again in a regular but peculiar and identifiable way—and showed that their periods of variation in brightness were positively correlated with their maximum brightnesses. She published a paper, "1777 Variable Stars in the Magellanic Clouds," with these results in the *Annals of the Harvard College Observatory* in 1908 as the sole author. It included the understated conclusion that "it is worthy of notice that . . . the brighter stars have the longer periods." By 1912, Pickering recognized the importance of her work, and so her follow-up paper, "Periods of 25 Variable Stars in the Small Magellanic Cloud," was published under his name, only, though he was kind enough to add the note "prepared by Miss Leavitt" to the publication. This relationship, now known as the Leavitt Law, was the critical discovery that allowed Harlow Shapley to discover the structure of the Milky Way, Edwin Hubble to discover that the Milky Way Galaxy is not the entire Universe and that most of the galaxies that make up the Universe are moving apart, and modern astronomers to use the Hubble Space Telescope to improve measurements of the distance scale of the Universe.

Cannon, Fleming, Maury, and Leavitt are just four of the more than forty women who were hired to make measurements of stars found in the Harvard College Observatory photographic plate collection in the years prior to World War I, starting in 1875 when the Observatory changed a policy such that it could hire women onto the staff. The first woman hired was Director William Rogers's wife, Mrs. R. T. Rogers, who would work at the Observatory for twenty-three years. That same year, Anna Winlock (1857–1904), the eldest daughter of the deceased former Observatory director Joseph Winlock, was put on staff, where she would remain a computer for twenty-eight years. Anna's sister Louisa (1860–1916) started her twenty-nine-year career as a computer in 1886. And in 1879, Selina Cranch Bond (1831–1920), the daughter of the first Observatory director, William Cranch Bond, joined the staff, where she would continue working for twenty-seven years.

Harvard computer Adelaide Ames (1900–1932) was Observatory director Harlow Shapley's first graduate student (starting in 1921) and in 1924 became the first woman to earn a MA in astronomy at Radcliffe. Together, they published "A Survey of the External Galaxies Brighter

than the Thirteenth Magnitude" (generally known as the *Shapley-Ames Catalogue of Bright Galaxies*) in 1932.

Another woman who started as a Harvard computer (1907–12) after receiving her AB degree from Radcliffe in 1907 was Margaret Harwood (1885–1979). She, however, spent most of her career elsewhere. In 1912, after receiving a fellowship from the Maria Mitchell Association on Nantucket Island, she stayed, becoming the director of the Maria Mitchell Observatory in 1916 after completing her MA degree at the University of California, thus becoming the first woman astronomer to direct an independent observatory in the United States. She remained as director until 1956 and spent her career measuring the variability of light received from stars and asteroids and mentoring several generations of up-and-coming women astronomers.

Margaret Walton Mayall (1902–95) spent the first thirty years of her career as a Harvard computer, but she is best known for the subsequent twenty years, which she spent as Director of the American Association of Variable Star Observers (AAVSO). She started working at the Observatory in 1924 and continued until 1955. After earning her MA in astronomy from Radcliffe in 1927, she worked in partnership with Annie Jump Cannon until 1941 and then completed Cannon's unfinished work, which she published in 1949 as *The Henry Draper Extension: The Annie J. Cannon Memorial*. Finally, beginning in 1954 and continuing until 1973, she served as Director of the AAVSO and oversaw the transition of the organization from an activity headquartered and run by the Harvard College Observatory into an independent, nonprofit, scientific organization.

Harvard was not the only observatory that used talented women as inexpensive labor. Annie Scott Dill Maunder (1868–1947) was hired as a human computer in 1890 at the Royal Observatory in Greenwich, thereby becoming one of the first women in England to be paid for her work in astronomy. Maunder is best known for the work she did with her husband, Walter, discovering the pattern in which over a period of eleven years sunspots appear at successively lower solar latitudes and then repeat this cycle. This so-called butterfly pattern is a manifestation of the twenty-two-year-long solar sunspot cycle. Along with Mary

Proctor, she was elected with the first cohort of women to become Fellows of the Royal Astronomical Society in 1916.

After completing a master's degree in astronomy at Mount Holyoke College in 1906, Jennie Belle Lasby (1882–1959) was immediately hired as the first woman computer at Mount Wilson Observatory (MtW), in California, where she would work until 1913, publishing an article on the rotation of the Sun and writing several articles on spectroscopy with Walter Adams. She then worked in 1915 with J. C. Kapteyn at Potsdam Observatory, taught at Carleton College for the duration of World War I as a war-replacement instructor, and then taught astronomy at Santa Ana College in California from 1919 until 1946.

Just months after Lasby started at MtW she was joined by Cora Gertrude Burwell (1883–1982), who, after graduating from Mount Holyoke in 1906, became the second of the female computers at MtW, where she would work until 1949. She would publish nearly forty papers in her career, including two catalogues of hot stars with bright hydrogen emission lines.

Many of these women had extraordinary careers as computers at the end of the nineteenth century and in the first decades of the twentieth. But they rose to distinction almost entirely by carrying out tasks assigned to them by male astronomers. Their educations and opportunities for leadership and advancement were limited. The glass ceiling above them was thick and impermeable.

Maria Mitchell (1818–89) carved a more independent path as America's first important female astronomer. Mitchell became famous after discovering a comet in 1847, for which she was awarded a gold medal by King Christian VIII of Denmark. She then worked for the U.S. Coast Survey, beginning in 1849, tracking the positions of planets, before being appointed to the faculty at Vassar College in 1865 and thereby becoming the first woman to hold a position as a professor of astronomy.

In the years immediately after Mitchell joined the faculty at Vassar, a few other women would receive faculty appointments as astronomers in the United States at small colleges, mostly in the Northeast. Immediately after graduating from Mount Holyoke College in 1866, Elisabeth

Bardwell (1831–99) became an instructor there and would remain at Mount Holyoke for the next thirty-three years. She published her observations of meteor showers in the magazines *Sidereal Messenger* and *Popular Astronomy*.

Susan Jane Cunningham (1842–1921), who studied at the observatories of Vassar, Harvard, Princeton, and Cambridge, helped found both the mathematics and the astronomy departments at Swarthmore College in 1869, becoming Swarthmore's first professor of astronomy that year and later also a professor of mathematics.

A decade later, in 1876, Sarah Frances Whiting (1847–1927) began her career on the faculty at Wellesley College as their first professor of physics, where she started their physics department and would teach Annie Jump Cannon (Wellesley, Class of 1884). Later, after learning astronomy under the tutelage of Edward Pickering at the Harvard College Observatory, she established and became the founding director of Wellesley's Whitin Observatory, built with funds donated by Mrs. John C. Whitin. During her career, she wrote popular articles about astronomy and a textbook for teaching astronomy.

In 1883, after studying astronomy for a year with Edward Pickering, Mary Emma Byrd (1849–1934) took up a position as first assistant at the Goodsell Observatory at Carleton College in Minnesota. She would eventually earn a PhD in astronomy at Carleton in 1904. In 1887, Smith College lured her away to become both Professor of Astronomy and Director of the Smith College Observatory, where she worked until 1906. Byrd wrote two textbooks on astronomy and contributed articles to *Popular Astronomy*.

Winifred Edgerton Merrill (1862–1951) was the first American woman to earn a doctoral degree in mathematics, doing so at Columbia in 1886. Her dissertation work, which focused on both mathematics and astronomy, included the calculation of the orbit of a comet. In 1887, she was offered a professorship at Smith College, but her marriage that year led her to give up on a career in mathematical astronomy; however, she did teach mathematics at the Oaksmere School for Girls in New York until 1926. The inscription on her portrait, which hangs in Columbia's Philosophy Hall, reads "She opened the door."

In the United Kingdom, one woman who found her own path to scientific accomplishment, despite her lack of formal education, was Mary Adela Blagg (1858–1944). Beginning in 1907, working first with Samuel Saunder and then with Karl Müller, she established the modern nomenclature used for lunar features, cleaning up the mess left behind by a handful of nineteenth-century astronomical mapmakers. Blagg was one of only four women (the others were Cannon, Leavitt, and Klumpke Roberts) who were among the 207 Individual Members of the International Astronomical Union at the end of its first General Assembly, held in Rome in 1922, she as part of Commission 17 on Lunar Nomenclature.

One place where, more than a century ago, women managed to have some presence in professional astronomy was in the founding in 1899 of the Astronomical and Astrophysical Society of America (AASA; renamed the American Astronomical Society [AAS] in 1914), with 11 women[1] among its 113 charter members. By 1910, women numbered 20 out of the 180 additional members,[2] and in 1912 Annie Jump Cannon was elected as treasurer (she would be re-elected six times), becoming the first woman astronomer to hold office in the nascent AAS.

Emily Elisabeth Dobbin (1874–1949) was one of the original 113 members of AASA and, with Caroline Furness, one of two women of the 39 members who were actually at Yerkes Observatory for that first 1899 pre-meeting. After earning her master's degree in astronomy at the University of Chicago in 1903 and publishing two papers in 1904, she briefly taught mathematics, first at the University of Missouri and then at a high school in St. Paul, Minnesota. While in Minnesota, she became deeply involved in the suffrage movement and published a newspaper, the *Minnesota Socialist.*

During the two decades that preceded the entrance of the United States into World War I, only ten women received PhDs in astronomy in the United States. Many of them followed their degrees with long, productive professional careers. In addition, at least two women earned PhDs in mathematics doing astronomy research and then spent long careers working in astronomy.

Just a year after Dorothea Klumpke completed her PhD in Paris, Margaretta Palmer (1862–1924) earned her PhD as an astronomer (the

degree was issued by the mathematics department) at Yale in 1894, calculating the orbit of Comet 1847 VI, the comet whose discovery had made Maria Mitchell, her undergraduate mentor at Vassar, famous. She later would compute orbits for three comets discovered by Caroline Herschel, those of 1786, 1788, and 1797, and, with Frank Schlesinger and Alice Pond, write the first *General Catalogue of Trigonometric Stellar Parallaxes*, published in 1924. Palmer spent her entire career at the Yale Observatory, holding titles of computer (1894–1912) and research assistant (1912–24) before being promoted to the rank of instructor in 1923.

Anna Delia Lewis (b. 1870) was likely the first woman to earn a PhD in astronomy in the United States, completing her dissertation "Variable Stars" at Carleton in 1896 using data collected at Goodsell Observatory. She published a single paper, in *Popular Astronomy* in 1915, on sunspot observations made in 1914. She taught astronomy for four decades at Carleton, Mount Holyoke, Albert Lea, and Lake Erie colleges before retiring in 1936.

Flora Ellen Harpham earned her PhD in astronomy at Carleton College in 1900 and was later appointed as professor of astronomy and mathematics at the College for Women in Columbia, South Carolina. She published one research article in 1892, on Comet Swift, and three later articles in *Popular Astronomy*, including one on some of the earliest astronomical photographs ever taken, the Rutherfurd photographs taken in 1864 and 1865. She later translated the book *Historical Sketch of the Foundation of the Metric System* from the original French edition.

Caroline Ellen Furness (1869–1936) earned her doctorate in astronomy at Columbia in 1900. Furness joined the faculty at Vassar College in 1903, where she remained until 1933. Furness studied variable stars, comets, and minor planets, wrote the textbook *Introduction to the Study of Variable Stars*, and was elected a Fellow of the Royal Astronomical Society in 1922.

Harriet Williams Bigelow (1870–1934) earned her PhD in astronomy at the University of Michigan in 1904—the same year Mary Byrd earned her doctorate at Carleton—and published eight papers, most on comets, over a twenty-four-year span. She was appointed Director of the Smith College Observatory in 1906, was promoted to professor and

department chair in 1911, and served as both Vice President and President of the AAVSO.

Anne Sewell Young (1871–1961) earned her doctorate in astronomy at Columbia in 1906. She began her professional career in 1899 as Director of Williston Observatory at Mount Holyoke. Later, with her PhD in hand, she transitioned from instructor to professor and remained at Mount Holyoke until her retirement in 1936. She was one of the eight astronomers, and the only woman of the eight, who in 1911 formed the AAVSO. She would serve as its vice president in 1922–24.

Edith Dabele Kast (1880–1967) was awarded her PhD in astronomy in 1906 at the University of Pennsylvania and continued work there, at Flower Observatory, as a University Fellow for Research in Astronomy for one year. Her dissertation, "The Mean Right Ascensions and Proper Motions of 130 Stars," was her only professional publication. She was elected to membership in AASA in 1904, among the second dozen women to join. Following her marriage in 1907 and move to Utah, her membership lapsed before 1910.

Ida M. Barney (1886–1982) spent her career in astronomy after earning a PhD in mathematics at Yale in 1911. After teaching at several women's colleges for a decade, she was hired in 1922 as the chief assistant to Frank Schlesinger, Director of Yale Observatory, and with him produced the twenty-three-volume *Yale Zone Catalogues* of stellar proper motions, containing data for the movements of more than 147,000 stars. Barney completed the last thirteen volumes over a period of fifteen years after Schlesinger's death in 1943.

Emma Phoebe Waterman (1882–1967; later Haas) and Anna Estelle Glancy (1883–1975) both earned their doctorates in astronomy at the University of California, Berkeley in 1913. Waterman's career ended almost as soon as it started—she published two papers on bright Class A stars and one titled "The Present Status of the Problem of Stellar Evolution" in 1913 but none afterward—marrying in 1914. She did, however, make variable star observations for many more years, and beginning in 1953 she assisted Director Margaret Mayall in the work of the AAVSO. Glancy published her observations of comets and on the distance to the star Polaris, working from the Observatorio Nacional in Córdoba,

Argentina, through the 1910s and then left astronomy to spend the rest of her professional career working for the American Optical Company, applying her knowledge of optics to commercial research.

Mary Murray Hopkins (d. 1921) earned her PhD in astronomy at Columbia in 1915, after which she published a short series of papers on the star 61 Cygni. Hopkins, who started teaching at Smith College in 1906, was appointed associate professor in 1916.

In the 1920s through 1930, only five more women earned PhDs in astronomy in North America.

In 1921, Priscilla Fairfield Bok (1896–1975) completed her PhD in astronomy at Berkeley. Immediately afterward, she took up a position on the faculty at Smith College while working, unpaid, as a researcher at Harvard. According to her astronomer-husband Bart, "My wife Priscilla did a lot of work at Harvard, and didn't even want a job. We felt we were both better off if she was a free agent and could do what she wanted to do." Of course, Shapley, the director at Harvard College Observatory, was happy to have her work for free, and Harvard University was not about to offer a faculty position to a woman. In later years, she took up teaching positions at Wellesley College and then at Connecticut College before giving up her paid professional career and accompanying her husband when he accepted positions first at Mount Stromlo Observatory in Australia and then at the University of Arizona. In work done over three decades in partnership with her husband, she became an expert on the Milky Way (writing *The Milky Way* with Bart in 1941) and showing that the process of star formation is active in the modern Universe.

In 1925, Cecilia Helena Payne (1900–1979; later Payne-Gaposchkin) completed one of the most important doctoral dissertations in astronomy of the twentieth century, working with Harlow Shapley at the Harvard College Observatory. In her dissertation, she showed that most stars have the same chemical composition and are composed primarily of hydrogen and helium.[3] Shapley had recruited her to be his graduate student in order to claim that Harvard had a graduate program in astronomy, not just an observatory; her degree, however, was awarded by Radcliffe College because at that time Harvard did not grant degrees to women.

Only a year later, in 1926, Allie Vibert Douglas (1894–1988), who previously had studied under and written a paper with Arthur Eddington, at Cambridge in 1923, earned her PhD in astronomy at McGill University, becoming the first Canadian woman to do so. She also was the first woman to serve as President of the Royal Astronomical Society of Canada. She later would write the first biography of Eddington, *The Life of Arthur Eddington*, and produced papers about cyanogen bands in stellar spectra and the CH^+ molecule in interstellar space. She continued at McGill as a lecturer for thirteen years before moving to Queen's University, Ontario, as a professor of physics and retiring in 1964.

Emma Williams Vyssotsky (1894–1975), working with Payne, earned her PhD in astronomy at Radcliffe College in 1930. Immediately after completing her degree, Williams Vyssotsky relocated to McCormick Observatory at the University of Virginia, where her husband, Alexander, had recently been promoted to assistant professor. She was hired as an instructor and would publish twenty-seven papers, most on the motions of stars and all of them jointly with her husband, over the years from 1933 through 1951.

Maud Worcester Makemson (1891–1977) received her PhD in astronomy at Berkeley in 1930. In 1932, she joined Furness on the faculty at Vassar as an assistant professor of astronomy and navigation and became director of the Vassar Observatory in 1936 (where she was the first astronomy instructor of Vera Florence Cooper [Rubin] [1928–2016]). Makemson was a pioneer in archaeoastronomy, in particular Polynesian and Mayan astronomy, and astrodynamics. Her monographs include *The Morning Star Rises: An Account of Polynesian Astronomy* (1941), *The Maya Correlation Problems* (1946), and *The Book of the Jaguar Priest* (1951). After her retirement from Vassar in 1957 she began appointments as a lecturer of astronomy and astrodynamics at the University of California, Los Angeles and a consultant to Consolidated Lockheed-California, at which time she cowrote the textbook *Introduction to Astrodynamics*. When she took up her appointment at UCLA, she was the only female faculty member there in astronomy, mathematics, or physics (and Virginia Trimble's [chapter 6] first astronomy instructor).

In this same era, Louise Freeland Jenkins (1888–1970) found a path to success in astronomy despite completing her education in 1917 with only a master's degree, earned under the tutelage of Anne Young at Mount Holyoke. Hired at Yale Observatory in 1932, she was assistant editor of the *Astronomical Journal* for sixteen years and wrote with Frank Schlesinger the second edition of the *Yale Catalogue of Bright Stars* in 1940 and the second edition of the *General Catalogue of Stellar Parallaxes* in 1935. She compiled the third edition of *Stellar Parallaxes* in 1952, as well as a 1963 supplement, on her own.

Merrill, Klumpke Roberts, Palmer, Lewis, Harpham, Furness, Byrd, Bigelow, Young, Kast, Barney, Waterman, Glancy, Hopkins, Bok, Payne, Douglas, Vyssotsky, and Makemson were all working to crack the glass ceiling that kept women in low-level helper roles in astronomy. In completing doctoral dissertations, they were asking their own scientific questions and using their considerable intellectual skills to make progress toward answering them. Nevertheless, for most of them their achievements combined with their professional knowledge and skills were not enough to allow them to join the old boys' club.

World War II triggered major employment opportunities that led to new careers for women, not just in industry but also in academia. After more than half a century during which women astronomers were limited almost entirely to research assistant positions at a small handful of observatories or faculty positions at women's colleges, a few women found themselves in the right places at the right times to do important work. Sometimes, they were able to take a step up the academic ladder; other times, the solidly entrenched rules that limited career opportunities for women won.

One woman who made enormous contributions, first to radar work for the Australian government's Council for Scientific and Industrial Research during World War II and then as a pioneer in the new field of radio astronomy, was Ruby Payne-Scott (1912–81). In 1933, Payne-Scott was the third woman to earn a BSc in physics at the University of Sydney; she would then earn a MSc in physics three years later. After discovering several kinds of radio bursts from the Sun and making important engineering contributions to radio frequency detectors, she was

forced into early retirement from astronomy in 1951 simply because she was married. A decade later she did return to work, but not to astronomy, teaching at an Anglican school for girls.

Henrietta Hill Swope (1902–80) earned a master's degree in astronomy at Radcliffe in 1928 and then worked for fourteen years as a Harvard Observatory computer making measurements of variable stars. During and after World War II, Swope worked for the U.S. Navy Hydrographic Office, computing long range navigation (LORAN) tables. After the war, Swope taught at Barnard College for five years and then teamed up with Walter Baade, at the Carnegie Observatories, as his research assistant. With Baade, she determined the distance to the Andromeda Galaxy to be 2.2 million light years,[4] discovered the Draco dwarf galaxy, and showed that the Cepheids in Andromeda are more like those in the Milky Way than like those in the Small Magellanic Cloud. Notably, several of the most important "Baade and Swope" papers were published in the years from 1961 through 1965, well after Baade had retired in 1958 and died in 1960.

As presaged by Annie Maunder, Margaret Huggins, and a few others, our more recent era also includes some women whose involvement in astronomy was furthered or even initiated by working with their better-known husbands, including some who also got their starts contributing to the war effort in the 1940s. These distaff astronomers included Martha Betz Shapley (1890–1981), Barbara Cherry Schwarzschild (1914–2008), Katherine C. Gordon Kron (1917–2011), and Antoinette Piétra de Vaucouleurs (1921–87).

After marrying Harlow Shapley in 1914, Betz Shapley abandoned her PhD work in German literature at Bryn Mawr College to follow Harlow Shapley in his career, moving first to Mount Wilson and then to Harvard. Self-taught in astronomy, she specialized in the study of eclipsing binary stars and managed to publish more than two dozen professional papers over a dozen years before abandoning astronomy in 1932 due to the pressure of family life. She returned to astronomy and wrote four more papers after 1946. She also calculated munitions trajectories during World War II and served on IAU Commissions 27 and 42.

Barbara Cherry was well on her way toward a career in astronomy, completing her coursework at Harvard in astronomy while a graduate student at Radcliffe and working at the MIT Radiation Lab, when she married Martin Schwarzschild in 1945. Although she wrote two research papers and a *Scientific American* article in the 1950s, all with Martin, her marriage limited and effectively ended her career.

Katherine C. Gordon studied astronomy at Vassar, Lund University, and again at Harvard College Observatory, before working at Lick Observatory from 1941 into 1943, at the California Institute of Technology in 1943–44, and at the Naval Ordnance Test Station in China Lake, California, in 1944–45. After marrying Gerald Kron in 1946, she followed him as he pursued his career but also managed to publish twenty-four papers about variable stars and edit the *Publications of the Astronomical Society of the Pacific* (1961–68).

Antoinette de Vaucouleurs published nearly eighty papers across half a century, despite having only an undergraduate degree from the Sorbonne. After marrying Gérard de Vaucouleurs in 1944, she worked as the assistant director at Mount Stromlo Observatory and then helped her husband and his collaborators at Lowell Observatory and the University of Texas, where she held a position as research scientist associate in the astronomy department for twenty-five years.

Helen Dodson-Prince (1905–2002), who completed her PhD in astronomy at the University of Michigan in 1934, was one of the first women for whom her advanced degree opened up a path for joining the faculty of a major research university. She held a faculty position at Wellesley College (1933–45) before being appointed to the faculty of Goucher College in 1945. Dodson-Prince relocated again in 1947, taking up a professorship at the University of Michigan. She specialized in the study of solar flares, with much of her early work done at the solar observatory at Meudon, near Paris.

After completing her PhD in astronomy at Radcliffe in 1931, Helen Sawyer Hogg (1905–93) followed her husband to the University of Toronto and joined the staff at David Dunlap Observatory, where she established her reputation by discovering variable stars in globular clusters. After serving as acting chair of the astronomy department at Mount

Holyoke in 1940–41, she returned to the University of Toronto and began teaching, as a substitute for the male faculty who had been called to military duty during World War II. She continued in this position after the war and in 1951 was belatedly promoted to a permanent faculty position.

Also in 1931, Charlotte Emma Moore-Sitterly (1898–1990) earned her PhD in astronomy at Berkeley. Moore had begun her career in 1920 at Princeton as a computational assistant to Henry Norris Russell and would continue to work with him into the 1950s. Moore established herself as an expert in atomic spectroscopy, working at Princeton until 1945 before relocating to the National Bureau of Standards and then the Naval Research Laboratory. Moore's *A Multiplet Table of Astrophysical Interest* and *An Ultraviolet Multiplet* became basic references for all astrophysical line identifications and also of great value to atomic physicists and chemists. Without these references the analyses of stellar atmospheres would not be possible.

E. Dorrit Hoffleit (1907–2007) completed her PhD at Radcliffe in 1938 working under the supervision of Bart Bok. She continued working at the Observatory until she was recruited to Aberdeen Proving Ground in 1943 to compute army artillery firing tables during the war and to White Sands Missile Range to work on Doppler tracking of captured V-2 rockets after the war. In 1948 she took a large pay cut in order to return to a computing position at Harvard Observatory, because that allowed her to return to her work with the Harvard plate collection. Then, in 1956, she accepted Yale Observatory director Dirk Brouwer's offer of a position that had her on the Yale Observatory research staff for six months and as director of the Maria Mitchell Observatory for the other half of each year. At Yale, she took charge of updating and editing what became the third (1964) and fourth editions (1982) and supplement (1983) of the *Yale Bright Star Catalogue* and wrote (with W. F. van Altena and J. T. Lee) the fourth edition (1995) of *The General Catalogue of Trigonometric Stellar Parallaxes*. She continued as director of Maria Mitchell Observatory until 1978, and during those years she left her imprint on modern astronomy by mentoring 102 women and three men in summer undergraduate research programs, including about 25 who

became professional astronomers,[5] among them Janet Akyüz Mattei (1943–2004; PhD in astronomy from Ege University in Turkey in 1982), who would go on to become the director of the AAVSO for thirty years.

Payne-Gaposchkin, meanwhile, persevered at the Harvard College Observatory for three decades, continuing to work in low-paid, low-prestige research positions because Harvard University did not allow women to be appointed to the faculty. The male astronomers who controlled the hiring of faculty at most American colleges and universities early in the twentieth century had little interest in diversifying their faculties by hiring women, no matter how talented. Nevertheless, Shapley had Payne-Gaposchkin giving lectures, though without an official appointment, and working with graduate students in their research beginning almost immediately after completing her degree. In 1945, after nearly two decades of teaching, her name was printed in the university course catalog for the first time. Another decade later, in 1956, she was at last appointed to a professorship. A few months later, she was tapped as Chair of the Department of Astronomy.

At the University of Chicago, a combination of World War II opportunities and the presence of Subrahmanyan Chandrasekhar led to a quintet of women earning PhDs at that institution in the 1940s.

Margaret Kiess Krogdahl (1920–2013) was the first woman to earn a PhD in astronomy at the University of Chicago, completing her degree in 1944 under the supervision of Chandrasekhar. After a three-year research fellowship at Yerkes Observatory, she moved with her husband, Wasley Krogdahl, who had also been a Chandra student, to Lexington, Kentucky, where he had been appointed to the faculty at the University of Kentucky. She published nine of her own papers, the last in 1960, and then edited his publications, including *The Astronomical Universe: An Introductory Text in College Astronomy*.

Merle Eleanor Tuberg Gold (1921–2017), who studied the Sun, followed quickly in Krogdahl's footsteps. She earned her PhD in astronomy in 1946 at Chicago, also working with Chandrasekhar, publishing her only two research papers along the way. She then took up a postdoctoral position in Cambridge, UK, where she met and married astrophysicist Thomas Gold, with whom she had three daughters. Her career

ended at about the time her family started, and it was said in her obituary that she had chosen family over science.

Marjorie Hall Harrison (1918–86) also completed a PhD in astronomy under Chandrasekhar, in 1947. After publishing a half-dozen papers in the 1940s on models of stars with hydrogen-depleted cores, she taught astronomy at Sam Houston State University in Huntsville, Texas.

The last two women who would complete PhDs in astronomy at the University of Chicago in the 1940s went on to very distinguished careers. Anne Barbara Underhill (1920–2003), who also worked with Chandrasekhar, completed her degree in 1948 and Nancy Grace Roman (1925–2018), who worked with W. W. Morgan, did so in 1949.

Underhill, born in Vancouver, Canada, worked as a postdoctoral scholar at Copenhagen Observatory for a year and then did research at Dominion Astrophysical Observatory in Canada until 1962, when she was recruited for and accepted a full professorship at the University of Utrecht in the Netherlands, finally joining NASA in 1970 for the remainder of her career. She specialized in studying hot (early spectral type) stars and computing numerical models of the atmospheres of stars.

Roman worked at Yerkes and McDonald Observatories until 1954 before moving to the Naval Research Laboratory, where she became head of the microwave spectroscopy group in the newly formed radio astronomy program. She then joined NASA in 1959.

Martha Elizabeth Stahr (Patty) Carpenter (1920–2013) earned her PhD in astronomy at Berkeley in 1945, taught at Wellesley from 1945 until 1947, and then was hired onto the faculty at Cornell University, where she was the first female faculty member there in the College of Arts & Sciences. She relocated from Cornell to the University of Virginia in 1965, where she remained until her retirement in 1985. As a radio astronomer, she studied the Sun and 21-centimeter line emission from the Milky Way. An additional, important part of her legacy may have been mentoring Vera Rubin's master's thesis on the kinematics of galaxies and thereby encouraging Rubin to pursue a career in astronomy.

Vera Florence Cooper Rubin completed her PhD in astronomy at Georgetown University in 1954, taught at Montgomery College for a year, and then did research again at Georgetown. Beginning in 1958, she

also assumed some lecturing duties there and was appointed as an assistant professor in 1962. After relocating to the Carnegie Institute of Washington in 1965, Rubin carved out one of the most distinguished careers in astronomy in the twentieth century. She set out to study the kinematics of spiral galaxies by measuring their rotation speeds, expecting to find that their rotation curves in their outer parts would be correlated with morphology; to her disappointment, they nearly all turned out to have similar rotation curves. Instead, her measurements demonstrated that a tremendous amount of unseen matter, dark matter, must exist in these galaxies in order for them to hold together.

One unusual PhD recipient was Frances Woodworth Wright (1897–1989), who earned her doctoral degree in astronomy at Radcliffe College in 1958, after earning her bachelor's degree from Brown nearly forty years earlier, in 1920. Hired as a computer at Harvard College Observatory in 1928, she continued working there as a research assistant until 1961. She made her reputation teaching celestial navigation to military personnel during World War II, beginning in 1942, and was later hired as a lecturer at Harvard in 1958 to teach celestial navigation to Harvard students and sailors, where the course continues to be taught by the Frances W. Wright Lecturer on Celestial Navigation. Wright wrote four books, three on celestial navigation, the last one published in 1980, and a fourth, *The Large Magellanic Cloud* (1967), written with Paul Hodge.

Martha Locke Hazen Liller (1931–2006), who also received her PhD in 1958, hers from the University of Michigan, specialized in observations of variable stars and planetary nebulae. In 1969, after working as a research fellow at the Harvard College Observatory, she was appointed Curator of Astronomical Photographs and in that position took charge of the Harvard Plate Archives for the next several decades.

Thus, at about the time when the space age began, in October 1957, a total of as few as eight women astronomers (Sawyer Hogg, Dodson-Prince, Payne-Gaposchkin, Douglas, Worcester Makemson, Carpenter, Rubin, and Wright)[6] held faculty appointments at any rank at major research universities in North America.

Only four more similar appointments would follow in the 1960s: Beverly Turner Lynds (b. 1929; PhD, UC Berkeley, 1955) was hired by

the University of Arizona in 1961; E. Margaret Peachey Burbidge (1919–2020; PhD, University College London, 1943) began as a member of the faculty at the University of California, San Diego in 1962; Elske van Panhuys Smith (b. 1929; PhD, Radcliffe, 1956) joined the University of Maryland faculty in 1963; and Ann Merchant Boesgaard (chapter 3) got started at the University of Hawai'i in 1967.

Thousands of dark nebulae are named for Lynds (e.g., Lynds 1551, or just L1551), as are the thousands of stars discovered within them (e.g., L1551 IRS 5), as a result of her publication in 1962 of *Catalogue of Dark Nebulae*. Lynds would serve in 1976–77 as the first female assistant director of Kitt Peak National Observatory.

Burbidge was the lead author on a landmark paper in 1957 on how heavy elements are made through nuclear fusion processes in stars. Generations of astrophysicists learned, only half jokingly, that the Big Bang made hydrogen and helium; then Burbidge, Burbidge, Fowler, and Hoyle made all the rest. Her list of firsts, which is nearly endless, includes first woman President of the International Astronomical Union's commission on galaxies, first female director of the Royal Observatory Greenwich, first woman President of the American Astronomical Society, and Inaugural Fellow of the American Astronomical Society. She also served as the founding director of the Center for Astrophysics and Space Science at UC San Diego, where she helped develop the Faint Object Spectrograph, one of the first instruments launched on the Hubble Space Telescope and which she used to find evidence for a supermassive black hole at the center of the galaxy M82.

Smith studied solar flares and the solar chromosphere and wrote a widely used undergraduate textbook, *Introductory Astronomy and Astrophysics*. After moving into university administration, she served as assistant provost and assistant vice chancellor at the University of Maryland and then as a dean at Virginia Commonwealth University.

In this same time period, Susan Kayser (b. ~1939) became the first woman to earn a PhD in astronomy at Caltech, in 1966. She was informed in the letter that initially rejected her from the program, "Women aren't really suited for observing on the long, cold, lonely nights." Upon completing her degree work, the Associated Press

described her accomplishment with the words "Astrophysicists getting prettier." Nevertheless, Kayser would carve out a distinguished career as a program manager at NASA and the National Science Foundation, working on the Helios and ISEE-3 (later called ICE) spacecraft and radio astronomy experiments at NASA and the Gemini Telescopes at NSF, before finishing her career at the Fermi National Accelerator Laboratory.

Also in the mid-1960s, Sachiko Tsuruta, born in Yokohama in about 1936, earned her PhD in astrophysics from Columbia in 1964, working with A.G.W. Cameron on the cooling of neutron stars, objects which, at that time, were not yet known to exist. Since then, she has become an expert on neutron stars, black holes, and supermassive black holes. After holding positions at the Harvard-Smithsonian Center for Astrophysics and the Max Planck Institute in Munich, she assumed a full-time faculty position at Montana State University in 1989.

In Europe, Julie Marie Vinter Hansen (1890–1960) received an appointment as observer at the University of Copenhagen Observatory, where she spent her entire career, making her the first woman to hold an appointment at the University of Copenhagen. Specializing in calculating orbits of comets and asteroids, she was first appointed as a computer in 1915 and began her university appointment after she finished her education in 1919. Beginning in 1920, she became the Danish editor of *Nordisk Astronomisk Tidsskrift* (Nordic Astronomy Review), and in 1922 she stepped into the role of assisting Elis Strömgren, the editor for the IAU's International News Service, in disseminating both the IAU Circulars (postcard announcements giving information about astronomical phenomena requiring prompt dissemination) and the Central Bureau of Astronomical Telegrams (for announcing new astronomical discoveries). In 1947, she replaced Strömgren as director of the International News Service and as editor of the Circulars and the Telegrams. In 1921, Vinter Hansen and Helene Marie Emilie Kempf (the wife of German astronomer Paul Kempf, who died in 1920) were the first two women elected as members of the Astronomische Gesellschaft (the German Astronomical Society).

In 1939, Frida Elisabeth Palmér (1905–66), having been trained by Knut Lundmark at Lund University, became the first Swedish woman

to earn a PhD in astronomy, publishing her measurements on the positions and proper motions of semi-regular variable stars. During World War II, she worked for the signals intelligence agency Försvarets Radioanstalt decoding Soviet navy messages; after the war, no longer active in astronomy, she taught mathematics and physics at the Halmstad grammar school.

In 1945, Wilhelmina Iwanowska (1905–99), who earned her habilitation degree from Stefan Batory University (now Vilnius University) in Poland in 1937, was a founding faculty member of the Nicholas Copernicus University in Toruń, Poland,[7] served as the first director of the Institute of Astronomy in Toruń, and was the first woman to serve as a vice president of the International Astronomical Union (1973–79).

In 1946, shortly after completing a doctoral degree in physical sciences at the University of Rome, Giusa Cayrel de Strobel (1920–2012) became the first woman appointed as Astronomer in Italy, taking up a position at Asiago Astrophysical Observatory and the University of Padua; after completing a second PhD in 1966, this time in astronomy, she would work for the rest of her career at the Observatoire de Paris and would serve as President of the IAU Commission on Stellar Spectra from 1982 to 1985.

Alla Genrikhovna Massevich (1918–2008) received her doctorate from Moscow University in 1952. She was the first Soviet astrophysicist to undertake theoretical calculations of the structure and evolution of stars and mass loss from stars. After completing her degree, she became Deputy Chairman of the Astronomical Council of the Soviet Academy of Sciences, a position she held for thirty-five years. Among her responsibilities was, beginning in 1957, the optical tracking of Sputnik satellites. In 1972, she would add to her duties a faculty appointment at the Moscow Institute of Geodesy and Cartography.

In 1962, Edith Alice Müller (1918–95), who earned her PhD in mathematics at the University of Zurich in 1943, joined Underhill as a female astrophysicist and faculty member at a European university when she was appointed to the faculty at the University of Neuchâtel, Switzerland. In 1965, Müller joined the professoriate at the University of Geneva. In a major work published in 1960 jointly with Leo Goldberg and

Lawrence Aller, Müller determined the abundances of the elements in the Sun.

In 1964 Margherita Hack (1922–2013), who completed a thesis on Cepheid variable stars at the University of Florence in 1945, was appointed as full professor at the University of Trieste, Italy, where she remained, as the only female astronomy professor in Italy through the time of her retirement in 1992. She was the first Italian woman to direct the Astronomical Observatory of Trieste.

In the 1970s, many astronomy departments at research universities in North America began to hire women. A more correct understanding, however, would be that many of them decided the time had arrived to hire one woman each.

In 1971, both Virginia Trimble (chapter 6) and Erika Böhm-Vitense (1923–2017; PhD, University of Kiel, 1951) landed faculty positions, Trimble at the University of California, Irvine and Böhm-Vitense at the University of Washington. Trimble may well have been the first woman to be the subject of a hiring competition for astronomy faculty positions, entertaining multiple offers both in 1968 and again in 1971.

Then Roberta Humphreys (chapter 7) broke through at the University of Minnesota in 1972, the same year Sandra Moore Faber (b. 1944; PhD, Harvard, 1972) joined the faculty at the University of California, Santa Cruz and Judith Pipher (chapter 12) entered the professorial ranks at the University of Rochester.

Silvia Torres-Peimbert (chapter 8) joined the faculty at Universidad Nacional Autónoma de México in 1973.

Two years later, in 1975, Yale University hired Beatrice Muriel Hill Tinsley (1941–81; PhD, University of Texas, 1966) and Michigan State University offered an appointment to Susan M. Simkin (1940–2021; PhD, University of Wisconsin-Madison, 1966). Tinsley, who likely was the first woman astronomer an Ivy League school had to compete for in a faculty search, chose Yale over an offer from the University of Chicago.

In 1979, Caltech hired Judy Cohen (chapter 11) and Arizona State University added Susan Wyckoff (b. 1941; PhD, Case Western Reserve University, 1967) onto their respective faculties.

Thus, one needed all the fingers on two hands, but no more, to count the number of female astronomers hired into professorships at major research universities in North America in the 1970s.

In 1980, Smith College renewed its century-long commitment to women and astronomy by hiring Suzan Edwards (b. 1951; PhD, University of Hawai'i, 1980).

In 1983, after a several-year hiatus in the hiring of women astronomers onto research university faculties in North America, Cornell hired Martha Haynes (chapter 16) and the University of California, Berkeley added Imke de Pater (b. 1952; PhD, Leiden University, 1980).

In 1984, Princeton University added Jill Knapp (chapter 13), the University of Massachusetts hired both Susan G. Kleinmann (b. 1945; PhD, Rice University, 1972) and Judith Young (1952–2014; PhD, University of Minnesota, 1979, and the daughter of Vera Rubin), Indiana University added Phyllis Lugger (b. 1954; PhD, Harvard, 1982), and Dartmouth College added Mary K. Hudson (b. 1949; PhD, UCLA, 1974).

In 1985, the University of Texas at Austin hired Harriet Dinerstein (b. 1954; PhD, UCSC, 1980); and in 1986, the University of California, Los Angeles added Jean L. Turner (b. 1954; PhD, UC Berkeley, 1984).

Also in 1986, the University of Delaware hired Barbara A. Williams, making her the first Black woman astronomer to hold a professorship in the United States. Williams, who made radio telescope observations of compact clusters of galaxies, was also the first Black woman to earn a PhD in astronomy in the United States, doing so in 1981 at the University of Maryland.[8]

Then, in 1988, Johns Hopkins University added Rosemary Wyse (chapter 20), in 1989 Penn State University hired France Córdova (chapter 17) and Princeton University added Neta Bahcall (chapter 9), and in 1990 Ohio State University hired Kristen Sellgren (b. 1955; PhD, Caltech, 1983). That made a total of fourteen more women hired into professorial appointments at major research universities in the United States through 1990.

Amazingly, through 1990 identifying and counting the women hired onto research university faculties in astronomy was fairly easy because the number remained so small. A few major astronomy programs didn't

diversify until the late 1990s or even later, but after 1990 tracking the many women both earning PhDs and receiving faculty appointments in astronomy in the United States becomes much harder because so many more women were earning doctoral degrees, completing postdoctoral appointments, and entering the professoriate.

Among the many scientific accomplishments during this period by these and other women, a few stand out, among them the discovery of pulsars (neutron stars) by S. Jocelyn Bell (later Burnell) (chapter 5) in 1967; the discovery in the late 1960s by Beatrice Tinsley that the luminosities and chemical make-ups of galaxies evolve over cosmic time; Vera Rubin's measurements from the early 1970s onward of the rotation curves of spiral galaxies, which later made clear that nearly all galaxies contain more dark matter than stars and gas, especially in their outskirts; the discovery in 1976 by Sandra Faber and Robert Jackson that the luminosities and orbital speeds of the stars near the centers of galaxies are correlated (the Faber-Jackson relation); and the discovery in 1989 by a team led by Margaret Geller (b. 1947; PhD, Princeton, 1974) and John Huchra of the Great Wall of galaxies that is part of the filamentary structure of the Universe.

Other firsts occurred over these years on the management and leadership side of the profession.

In 1937, Maude Verona Bennot (1892–1982; MS, Northwestern University, 1927) became the acting director of Chicago's Adler Planetarium, a position she would hold until 1945, making her the first woman in the United States, and likely the world, to head a planetarium facility; Bennot was forced out of her job and of a career in astronomy in 1945 when the president of the Chicago Park District board engineered her removal.

In 1959, Nancy Grace Roman was appointed as the first chief of astronomy and relativity in the Office of Space Science at the newly created organization called NASA. She is credited with nurturing the development of several space-based telescopes, including the International Ultraviolet Explorer (IUE), the Cosmic Background Explorer (COBE), and the Hubble Space Telescope (HST), and is widely known as the "mother" of the Hubble. In her honor an infrared telescope due to be

launched by NASA in the mid-2020s has been renamed the Nancy Grace Roman Space Telescope.

In 1976, Edith Müller became the first woman to be elected as general secretary of the International Astronomical Union, serving in that role until 1979.

In 1976 Sidney Wolff (chapter 4) was appointed as associate director of the Institute for Astronomy at the University of Hawai'i; she served as acting director in 1983–84, became director of Kitt Peak National Observatory from 1984 until 1987, and then was appointed director of and led the National Optical Astronomy Observatory until 2001.

In 1980, Andrea Kundsin Dupree (b. 1939; PhD, Harvard University, 1968) became the first woman and youngest person to serve as associate director of the Harvard-Smithsonian Center for Astrophysics.

In 1983, Neta Bahcall (chapter 9) was appointed as chief of the General Observer Support Branch for the newly formed Space Telescope Science Institute.

And in 1985 Catherine Cesarsky (chapter 10) became the first woman selected as a principal investigator on a European Space Agency project.

As with the progress over the last several decades toward gender equity in management and leadership opportunities, the awarding of important national and international honors is also evolving. Some examples follow.

1959: E. Margaret Burbidge and her husband, Geoffrey, shared the Helen B. Warner Prize for Astronomy, given annually since 1954 by the American Astronomical Society "for a significant contribution to observational or theoretical astronomy during the five years preceding the award." No other woman had previously received this honor, nor would any other woman receive this honor again for nearly fifty years, until Sara Seager (chapter 33) did so in 2007.

1976: Cecilia Payne-Gaposchkin was recognized with the Henry Norris Russell Lectureship, given annually since 1946 by the American Astronomical Society "on the basis of a lifetime of eminence in astronomical research." She was the first woman to present this lecture. The others who have been recognized as Russell Lecturers are E. Margaret

Burbidge (1984), Vera Rubin (1994), Margaret Geller (2010), Sandra Faber (2011), and Ann Boesgaard (2019, chapter 3).

1989: Jocelyn Bell Burnell (chapter 5) received the Herschel Medal, awarded by the Royal Astronomical Society annually since 1974 for "investigations of outstanding merit in observational astrophysics." As of 2021, no other woman has received this award.

1989: Martha P. Haynes (chapter 16) became only the second woman to receive the Henry Draper Medal, awarded every four years since 1886 by the U.S. National Academy of Sciences "for investigations in astronomical physics." She shared this prize with Riccardo Giovanelli for their work in constructing "the first three-dimensional view of some of the remarkable large-scale filamentary structures of our visible Universe." Annie Jump Cannon was the first woman to receive the Draper Medal, nearly sixty years before, in 1931. No other women have won this award.

1994: Edith Müller became the first woman to receive the Prix Jules-Janssen, for her work in solar spectroscopy. The Prix Jules-Janssen has been awarded annually since 1897 by the Société Astronomique de France for international distinction. Elizabeth Nesme-Ribes (1942–96) shared the award (posthumously) in 1997, as did Thérèse Encrenaz (b. 1946) in 2007. In 2009, Catherine Cesarsky (chapter 10) was the fourth woman so recognized; Suzanne V. Débarbat (b. 1928) received the award in 2013, Suzy Collin-Zahn (b. 1938) did so in 2015, as did Ewine van Dishoeck (chapter 22) in 2020.

1996: Vera Rubin was awarded the Gold Medal by the Royal Astronomical Society, this society's highest honor, for her work in studying galaxy rotation curves. She was the first female awardee since Caroline Herschel received her Gold Medal 168 years earlier. In 2005, E. Margaret Burbidge and Geoffrey Burbidge shared the Gold Medal. In 2020 Sandra Faber and in 2021 Jocelyn Bell Burnell (chapter 5) received the Gold Medal.

2003: Virginia Trimble (chapter 6) became the first person designated as President of a second International Astronomical Union Division (XII, Union-Wide Activities), after serving as President of Division VIII (Galaxies and Cosmology) from 2000 to 2003.

2004: Vera Rubin was the first woman to receive the James Craig Watson Medal, awarded every two years since 1887 by the U.S. National Academy of Sciences "for outstanding contributions to the science of astronomy," for "her seminal observations of dark matter in galaxies, large-scale relative motions of galaxies, and for generous mentoring of young astronomers, men and women." Margaret Geller was honored with this award in 2010 ("for her role in critical discoveries concerning the large-scale structure of the Universe, for her insightful analyses of galaxies in groups and clusters, and for her being a model in mentoring young scientists"), as were Ewine van Dishoeck in 2018 (chapter 22, "for her many important contributions to the field of molecular astrophysics and astrochemistry") and Lisa Kewley (b. 1974) in 2020 ("for her fundamental contributions to our understanding of galaxy collisions, cosmic chemical abundances, galactic energetics, and the star-formation history of galaxies").

2006: Catherine Cesarsky (chapter 10) was elected President of the International Astronomical Union (IAU) for the 2006–9 term. She was the first woman to lead the IAU since it was founded in 1919. Silvia Torres-Peimbert (2015–18; chapter 8) was the second, Ewine van Dishoeck (2018–21; chapter 22) the third, and Debra Elmegreen (b. 1952; 2021–24) the fourth.

2012: Jane Luu was the first woman to win or share the Shaw Prize in Astronomy, which was established in 2002. She shared this prize with David Jewitt for their discovery and characterization of trans-Neptunian bodies. In 2021, Victoria M. Kaspi and Chryssa Kouveliotou became the second and third women so honored when they shared the Shaw Prize in Astronomy for their contributions toward our understanding of magnetars.

2017: Cathie Clarke (chapter 25) was the first woman recipient of the Eddington Medal in Theoretical Astrophysics, awarded annually since 1953 by the Royal Astronomical Society for "investigations of outstanding merit in theoretical astrophysics." In 2018, Claudia Maraston (b. 1966) was the second woman awarded the Eddington Medal, and in 2021 Hiranya Peiris (chapter 34) became the third.

2019: E. Margaret Burbidge was selected as the Inaugural Fellow for the newly created Fellows of the American Astronomical Society.

2020: Andrea Mia Ghez became the first woman to earn the Nobel Prize in Physics for work in astrophysics, sharing the prize with Reinhard Genzel "for the discovery of a supermassive compact object at the center of our Galaxy" and with Roger Penrose, for his work on the formation of black holes.

Notes

1. Emily Elisabeth Dobbin, Williamina S. Fleming, Lucy Ames Frost, Caroline Furness, Ida Griffiths, Antonia C. Maury, Mable C. Stevens, Sarah F. Whiting, Mary W. Whitney, Elva G. Wolffe, and Ida Woods.

2. Leah Brown Allen, Harriet W. Bigelow, Louise Brown, Mary E. Byrd, Mary Ross Calvert, Annie Cannon, Mrs. Henry Draper, Margaret Harwood, Flora E. Harpham, Ellen Hayes, Mary Murray Hopkins, Edith Kast, Eleanor A. Lamson, Jennie B. Lasby, Henrietta Swan Leavitt, Mary Proctor, Helen M. Swartz, Ida W. Whiteside, Mrs. John C. Whitin, and Anne S. Young.

3. The concept that all stars have the same chemical composition was accepted immediately, but the dominance of hydrogen in stars was only embraced much later.

4. The best modern value for this distance is 2.5 million light years (765 kpc).

5. In chronological order: Margo Friedel Aller, Andrea Knudsen Dupree, Barbara Welther, Gretchen Luft Hagen Harris, Nancy Houk, Martha Safford Hanner, Diane Reeve Moorhead, Nancy Remage Evans, Catherine Doremus Garmany, Jane Turner, Jean Warren Goad, Karen Alper Castle, Marcia Keyes Lebofsky Rieke, Judy Karpen, Karen Kwitter, Esther Hu, Bonnie Buratti, Harriet Dinerstein, Melissa McGrath, Constance Phillips Walker, John Briggs, Deborah Crocker, Edward Morgan, and Karen Meech.

6. By 1958, Williams Vyssotsky was no longer involved in astronomy; she published her last paper in 1951.

7. At the end of World War II, when the USSR pushed its borders westward, many of the Polish faculty at Vilnius University relocated westward to Torun and started a new university.

8. Williams would be followed by Mercedes T. Richards (1986, University of Toronto), Jarita C. Holbrook (1997, UC Santa Cruz), and Dara Norman (1999, University of Washington; chapter 32) as Black women earning PhDs in astronomy.

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