GENDER AND SCIENCE: WOMEN IN AMERICAN ASTRONOMY, 1859–1940

Women measured plates and reduced data in the great factory observatories, helping raise American astronomy to world-class status while they themselves were relegated to second-class status.

John Lankford and Rickey L. Slavings

Historically, the division of labor within American astronomy was gender specific. Although the field took in large numbers of women, gender dictated who collected data, who reduced it, who analyzed it and who published the results. The assignment of roles reflected the perceptions male astronomers had of females, and those perceptions in turn mirrored the values of American culture.

The differences in the careers of men and women in astronomy began with inequalities in the available entry-level positions. From that point on, women's careers developed in the context of a dual labor market that shunted most females onto a track with limited mobility, low pay and little room for intellectual independence. Only at the women's colleges did female astronomers have freedom to choose research problems, but they were limited by the constraints of teaching institutions. In contrast, many men were able to move upward. The reward system of astronomy also treated men and women differently.

World War II transformed American science. For astronomy, the two decades after the war appear to be a golden age. Yet during this period of rapid growth, the status of women in the American astronomical community did not change significantly. Only in the 1950s did the first woman become a tenured professor of astronomy at Harvard, while the Mount Wilson and Palomar observatories permitted the first women astronomers to use their facilities in the mid-1960s. In the 1970s, with the passage of equal-opportunity legislation, the establishment of affirmative-action programs and the creation of committees on the status of women in scientific societies and academic institutions, the picture began to change. The degree, direction and rate of change are matters of debate.

Many jobs for women in astronomy were created in response to the sharp increase in data acquisition by photography. The situation is analogous to the use of female scanners in cosmic ray, nuclear and particle physics beginning in the late 1940s. Just as those women scanned millions of nuclear emulsions looking for rare interactions, so had earlier women examined plates for novel stellar spectra, new variable stars and novas.

This article focuses on women in the American astronomical community between 1859 and the coming of World War II. During this period 1205 individuals met our criteria—employment in an observatory or astronomy department, publication of research in astronomy or recognition by other astronomers—for inclusion as active members of the American astronomical community. Fully a third of these—426—were women. What was it about astronomy that drew women to its ranks, and what happened to them once they entered the field?

The experience of women in astronomy is one of the best-documented case studies of women as workers in large-scale science projects currently available, and ought to be of interest to all physical scientists. By illuminating problems of gender-based inequality and discrimination in the sciences, history can help us form and implement policy. Historians of science have paid special attention to this subject, due in part to the path-breaking work of Margaret Rossiter, which has helped raise the study of women in science to a major area of inquiry.

Astronomy as a field for women

Structural and institutional changes in American astronomy help explain why the field offered employment to

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Computer measuring astronomical plates, around the 1890s. Observatories employed women as computers to examine photographic plates for novel stellar spectra, new variable stars, novae and other objects. (Courtesy of Brenda Corbin, US Naval Observatory.)

women. By the 1890s major observatories were beginning to resemble industrial factories. The latest research technologies, most of which involved photography, increased the amount of data collected exponentially, and so reduction and analysis had to be routinized. The organization of work in the industrial factory provided a useful model. Work was broken down into component parts, and people with unequal levels of skill all became part of the production of knowledge.

At the Dudley Observatory, for example, where Lewis Boss was laboring on his great study of stellar proper motions, female high school graduates were considered competent to carry out the lengthy reduction of transit-circle data. Astrophysicists at Harvard and Mount Wilson demanded a more skilled labor force, often selecting their female assistants from the ranks of women's-college graduates. A clear-cut division of labor obtained in these research factories. Men observed at the telescope and carried out the final discussion of the data. Women measured spectrograms, computed star places or reduced photometric data.

Some scientists and historians of science are uncomfortable looking at these research institutions as knowledge factories. This discomfort may stem from a feeling that the sciences, and in particular the creation of scientific knowledge, have a privileged status, beyond the influence of economic, social or political events. However, to insist on the cultural and political autonomy of the sciences is to close off important avenues for understanding the development of the scientific enterprise.

The expansion of higher education provided a second source of employment for women in astronomy. Before the Civil War only a few colleges admitted women. After mid-century, however, the movement to create colleges for women gained momentum. Mount Holyoke and Vassar were early in the field with astronomy offerings. They were soon followed by Smith. Of the "Seven Sisters"—the prominent New England women's colleges—these three institutions developed strong astronomy departments. Their graduates often worked in the great factory observatories, and a few went on to take advanced degrees and return to one of the women's colleges to teach. The rapidly expanding state universities of the post-Civil War era did not provide significant employment in astronomy for women.

Demographics. We examined three cohorts of the 426 women who worked in astronomy between 1859 and 1940. In 1859 Maria Mitchell was the lone female astronomer in the United States. In the second cohort, made up of those who began their careers between 1860 and 1899, our data indicate that the number of women rose to 56, or 18.3% of the community. The third cohort, 1900–40, included 344 women, who made up 43% of the community.

While the data are far from complete, it appears that before 1900 more than half the women were born on the East Coast. To be sure, the proportion declined from the second to the third cohort, while the Midwest increased its share. Only after 1900 did the South and the Rocky Mountain region make any contribution to the pool of women working in astronomy. The Pacific Coast contributed both to the second and third cohorts.

Data on marital status are available for about one-third of the astronomical community in the period we studied. Seventy-three percent of this group married. This includes 167 men and 62 women. Before World War II it was common for women to choose between a career in science and marriage. This choice was dictated not only by custom but, for those who married other scientists, by strict nepotism rules as well.

Cultural norms. By the 1840s middle-class urban American culture had come to believe that men and women occupied separate social and psychological spheres. For example, men were competitive and success-

ful in business, while women excelled in art. Women also were credited with more patience than men, and so were thought to deal easily with routine tasks.

Mitchell, no less than other Americans of her generation, was imbued with the culture's values regarding gender-specific roles. "The eye that directs a needle in the delicate meshes of embroidery will equally well bisect a star with the spiderweb of a micrometer," she wrote. "Routine observations . . . dull as they are, are less dull than the endless repetition of the same pattern in crochetwork." Again and again, the first director of the Vassar College Observatory returned to the theme of special female skills involving patience.

Cultural norms are just as important in defining roles in a scientific community as they are in any other realm of society. Science is embedded in a cultural context that prescribes many of the values and behaviors of its practitioners. Cultural values and norms also condition perceptions. The process of evaluating students and colleagues, for example, depends in part on cultural factors and not completely on purely objective standards.

The outlook of male scientists

To explain women's status in American astronomy, it is necessary to gain some understanding of the ways men viewed them. The letters of male astronomers frequently reveal their perceptions of women. The physical and emotional strengths of women were major areas of concern. Female students were sometimes characterized as excessively emotional or nervous and given to bouts of ill health. These tendencies impaired their usefulness as assistants. They were also said to be shy and reluctant to speak up in class. Compared with that of men, the progress of women toward graduate degrees was seen as erratic. Employers and chairmen of graduate departments worried that women would get married and leave the field: This would mean the loss of investments in graduate education or on-the-job training.

In evaluating women, male scientists tended to focus on their ability to do routine work. Indeed, some recommendations read as if they were descriptions of machines. Frank Schlesinger, longtime director of the Yale University Observatory, was quite clear in his evaluation of women. He viewed women as superior to men at routine work that called "for patience and great care to avoid errors." But, he insisted, "according to my experience, women are not as creative as men of equal training."

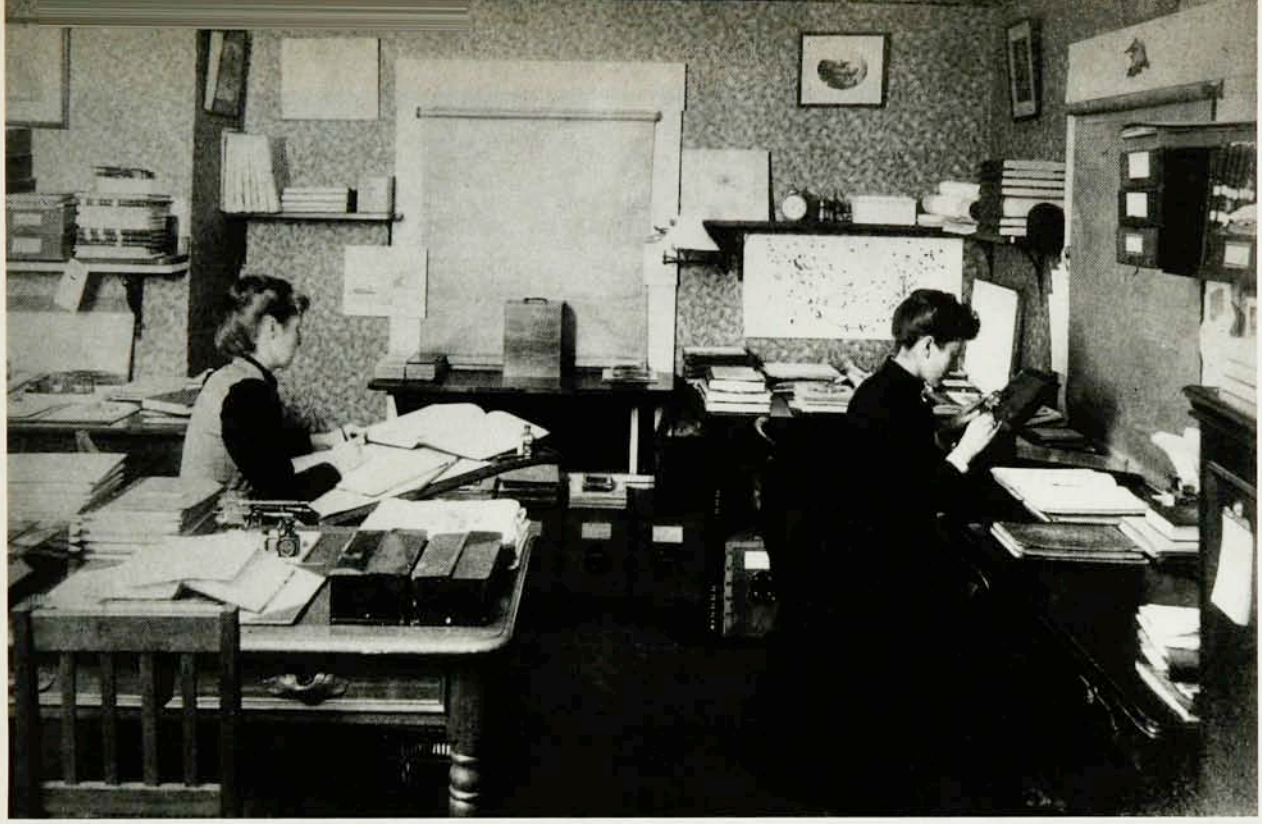
A few individuals reached "superwoman" status. Williamina Paton Fleming, the first woman to hold a formal or "corporation" appointment at Harvard, is an example. She not only supervised the female assistants at Harvard College Observatory and maintained the plate collection but as a single parent, raised a son and saw him through a degree at MIT. Oxford astronomer Herbert H. Turner recalled of Fleming, "She left her heavy daily labours at the observatory to undertake on her return home, those household cares of which a man usually expects to be relieved." But "she was fully equal to the double tasks, as those who have had the good fortune to be her guests can testify." Turner went on to note that Fleming "yielded to none in her enjoyment of a football match, especially between Harvard and Yale."

If Fleming reached superwoman status, the majority were quickly forgotten. Double-star expert Robert Grant Aitken, replying to an inquiry for information on women at Lick Observatory, found himself unable to recall anything of special importance about those women who passed through Lick as assistants or graduate students. Indeed, in 1922 the Lick administration permitted a 16-year veteran, Adelaide Hobe, to accept a better position elsewhere rather than offer her a promotion.

Men accepted women as workers on the assembly line in the great factory observatories and admitted them into their seminars, but they remained ambivalent. Around 1920 Robert H. Baker, director of the Laws Observatory at the University of Missouri, wrote of one graduate student, "While unfortunately she is not a man, I believe she is handicapped by her sex less than any aspirant I have known."

Male ambivalence was made abundantly clear to Wellesley physics and astronomy professor Sarah Frances Whiting. On a European tour in the 1880s, Whiting spent an afternoon in the laboratory of a famous researcher. Then they retired to his library to talk science. The great man, however, had other problems on his mind. He pointedly asked Whiting, "If all the ladies should know so much about spectroscopes and cathode rays, who will attend to the buttons and the breakfasts?" In addition to cultural stereotypes, the highly pragmatic issue of "but-

Cecilia Payne-Gaposchkin (left) and Annie Jump Cannon in 1938. Payne-Gaposchkin received the first PhD given by the Harvard astronomy department. Cannon was a spectroscopist at the Harvard Observatory. (Photo courtesy of Owen Gingerich, Harvard–Smithsonian Center for Astrophysics.)



Williamina Fleming (right) at Harvard in 1891, examines a plate while Mable Stevens works as recorder. (Photo courtesy of Gingerich.)

tons and breakfasts" helped to shape men's perceptions and evaluations of women.

The education of women astronomers

Between 1860 and 1899, the top four producers of women ABs in astronomy were the New England women's colleges Vassar, Smith and Holyoke, and Carleton College in Minnesota. Carleton and Vassar led in turning out MAs in astronomy. Carleton and Yale led in producing women doctorates in astronomy before 1900, and Columbia ranked second.

After 1900 the situation began to change. While the women's colleges and Swarthmore still led in producing undergraduate degrees in astronomy, Northwestern and the University of California joined the list of top producers of women baccalaureates in astronomy. At the MA level, Radcliffe held pride of place, followed by California, Chicago and Smith. From 1900–40 women most frequently earned doctorates at state universities, with Radcliffe and Chicago, both private institutions, rounding out the list of leading producers.

On the whole these data reflect larger trends in the history of science education for women. The women's colleges provided a nurturing psychological environment and rigorous training in astronomy, physics and mathematics. Many women remained to take the master's degree before entering the larger world to compete for a doctorate.

Another indicator that illuminates astronomy education for women is the undergraduate origin of female PhDs. Which institutions produced the most majors who went on to earn the doctorate? Between 1860 and 1899 Vassar led, with Carleton close behind. After 1900 Vassar continued to dominate the field, but with a significantly smaller share of the total market. California and Northwestern tied for second place, while three other women's colleges shared the third spot with coeducational Swarthmore.

Aspirations. We rarely find much information about the dynamics that impel individuals to select careers in science. The Vassar archives provide an exception to this rule. In the papers of Caroline Furness (Vassar class of 1891), who succeeded Mary Whitney (Mitchell's student) as professor of astronomy and director of the Vassar Observatory, are some documents that throw a highly revealing light on the aspirations of women.

Early in her student days at Vassar, Furness came under the spell of Whitney and fell in love with astronomy. Soon Whitney provided Furness with a desk in the observatory and her own observing book. As graduation approached, Furness's family was apparently pressuring her to return home and take a teaching job in a local high school. But she had other ideas.

Writing to her father in the spring of her senior year, Furness went to great lengths to justify her decision to undertake a career in science. At the outset, Furness made it clear that she did not aim "to become an astronomer, but [rather] a teacher of astronomy. The opportunities for being strictly an observer would never come to me. I aspire only to be a teacher." Thus she set an upper limit to her aspirations. To achieve her goal, Furness indicated to her father, graduate study was needed.

Furness went out of her way to justify further education. Her arguments, based on what later generations would call sexual politics, must have sounded daring in the early 1890s. She assured her father that it was not a case of "studying just for the sake of studying. I only want to prepare myself for the highest place—just as any young man might." Rather than waiting "for some young man to come along to marry me," she argued, "I want to prepare myself to live a useful and happy life without marriage,

Anna Palmer Draper (seated at right), widow of Henry Draper, checks on progress of the Henry Draper Memorial while visiting Harvard in the early 1890s. The Draper Memorial, a large-scale study of stellar spectra, opened up many new positions at Harvard, most of which were filled by women. Williamina Fleming is standing at the far right. (Photo courtesy of Gingerich.)

and then, if the right one comes along, well and good, I shall take him, but I shall not be obliged to take a man just for the sake of a home." Furness went on to remind her father that "all women cannot find just the right man—and I do not wish to be a party to an unhappy marriage."

Furness asked her father not to think her "selfish in planning so for myself." After all, "I must make my own way in the world. I have ability and interest, and why should I not rise to as much distinction in my profession as any man? If I were your son instead of your daughter, you would fully approve of my ambition."

The young scientist assured her father that she would rather live at home than anywhere else in the world. But she was not going to be a woman who sacrificed herself for her family. Instead, Furness turned the tables. "When I am a professor in some college, with a large salary, you shall [come and] live with me and be an advisor of all the girls."

Twenty years later, Phoebe Waterman wrote to her teacher, Professor Caroline Furness. Since taking an MA, Waterman had been a "computer" in the Pasadena offices of the Mount Wilson Observatory. Through the intervention of Furness, Waterman secured a Vassar fellowship and planned to begin doctoral work in astronomy at California in 1911. The chairman of the Berkeley astronomy department, Armin O. Leuschner, described Waterman as one of the most unusually well-prepared women the department had ever had.

Writing to her teacher, Waterman indicated aspirations far removed from those Furness had revealed in 1891. "But *Oh*, I do want so much a position as astronomer, part of my work with the instruments and part with the reduction of my plates, as men here [at Mount Wilson] have." Then Waterman went on to indicate how her goals differed from those of Furness two decades earlier: "I never did want the teaching. But it is very bold and presuming of a woman to think of such positions I suppose!

"They think so here" at Mount Wilson, she added ruefully.

Waterman took the PhD in 1913, but soon married and left the field, probably justifying the worst fears of some of the male faculty and fulfilling the wishes of others. How sad her comment to Furness rings down the years: "Then Hurrah for a little share, just a little one, in the big work you are all busy in." As Mrs. Phoebe Hass, Waterman's share proved to be more buttons and breakfasts than observations and monographs.

Pay and career choices

In many ways, Mitchell exemplifies women in astronomy. Her career experiences foreshadowed choices and decisions future generations of women would face in a variety of institutional settings.

In 1849 Mitchell accepted the position of computer with the newly established Nautical Almanac Office. Her acceptance letter indicated a sense of deference and self-deprecation in excess of that demanded by her Quaker upbringing. Mitchell feared that she had undertaken "a task for which I am not competent." The young woman, who had already digested the writings of the European masters of celestial mechanics, asked for "advice or information . . . as to the best means of fitting myself for the work." Frequently the letters of female astronomers to their male colleagues reflected a similar tone of deference.

Equal pay for women scientists was seldom a matter of public debate in the 19th century. In the discussions that led to Mitchell's being offered an appointment at Vassar, the men involved considered the question of salary. Charles S. Farrar, Vassar professor of mathematics and natural science, argued that a "moderate salary from the college" would "be both honorable and satisfactory to Miss M., since she will, of course, continue to serve the government [at the Nautical Almanac Office] and receive a government salary."

As it turned out, Mitchell's salary was only one-third that of the male professors: $800 to the men's $2500. Mitchell and her other female Vassar colleague, the college physician, battled the administration on the question of equal pay, but with little success and sometimes considerable acrimony. Forays into college politics left Mitchell disillusioned. Eventually she wrote, "Devote myself more and more to my own department—try to be loyal to the stars but keep away from the administration as much as possible."

Maria Mitchell and students at Vassar, around the 1880s. Mitchell was the first female astronomer in the United States. (Photo courtesy of Gingerich.)

During the interview process, an emissary of Matthew Vassar, the college's founder, visited Mitchell in her New England home and sent back a glowing report. "Miss Maria" was not only "the most accomplished Astronomer of her Sex in the world" but could deal with buttons and breakfasts as well. "The day I spent" with the Mitchell's, the emissary noted, "their domestic was absent," so "Maria prepared dinner and presided in all the housewifery of their cozy establishment—without parade, and without any apparent deficiencies." No bluestocking intellectual she!

A fascinating turning point in Mitchell's scientific career is revealed by a small notebook preserved in her papers in the Vassar archives. Undated and nondescript, the little notebook contains descriptions of the Vassar instruments, hints on working the chronograph and discussions of observing transits. By far the most compelling entries relate to fundamental career decisions that faced Mitchell after she became a Vassar professor.

Mitchell felt she had two options. Her "1st Plan" stressed a wide range of projects in observational astronomy: "Observations upon double stars—colors—spectroscope experiments—Also sweep for comets and examination of planets and of large stars for unknown companions—Also variable stars." Mitchell concluded that "the above would be popular and pleasing and would make [a] show."

Her "2nd Plan" stands in sharp contrast to the first: "To settle down upon some specific point and *plod*. It might be one of the smaller planetoids." Mitchell realized that developing a definitive orbit for an asteroid "would take time and would be tedious." The great advantage of such a line of research was that "it would be solid and endure for 100 years."

Ever thoughtful and reflective, Mitchell was not content to end her discussion at this point. She examined the consequences of the two plans: "The 1st plan would be likely to interest the girls [at Vassar] and would probably result in . . . discoveries." But, she surmised, "the 2nd plan would be more mathematical and would *in time* gain a real solid reputation."

Mitchell chose the first plan. To be sure, she was constrained by institutional circumstances. Lengthy and expensive research programs were a luxury at the women's colleges during the second half of the 19th century. Soon enough, Mitchell's notebooks included recipes for gingersnaps as well as data recorded at the telescope.

Mitchell's first plan foreshadows research strategies later adopted at the women's colleges. Observational astronomy, in keeping with available instrumentation, defined the activities of the women astronomers. Comets were followed and positions carefully measured so that orbits could be computed with the aid of advanced students. Sunspots, variable stars and occultations formed a major portion of observing programs. Mitchell often searched for new planetary satellites, but she seldom found time to reduce her observations and compare them with the positions of known objects. She also observed planetary markings. Working in her sitting room after breakfast she would attempt to recapture with watercolors the delicate hues of Mars, Jupiter or Saturn.

Vassar students remembered Mitchell as a great teacher and moral exemplar. But their wonderful tribute, preserved in the college songbook ("Good Woman That She Am"), had little to say about her scientific pursuits.

Comparing the careers of women and men provides empirical evidence of discrimination. Controlling for educational attainment, women tended to begin their careers at lower positions than did men with the same education. Such differences in entry-level positions have long-term consequences, because first jobs go far in determining future career development. For those who worked on the assembly lines of the great factory observatories, there was virtually no room to select problems or otherwise engage in independent research. Faculty at the women's colleges were sharply constrained by available instrumentation and institutional imperatives.

Women and the reward system

Any discussion of women and the reward system of American astronomy must begin with a consideration of the lengths of their careers. Fully 50% of the women active in the American astronomical community between 1859 and 1940 had careers whose lengths did not exceed five years. Indeed, for 22% of all women in astronomy during this period, careers lasted between one and two years. Only 25% were still active after 14 years. This figure dropped to 20% by 18 years. Only 12% had careers longer than 25 years.

While these data demonstrate the short-term nature of female employment in the American astronomical community, they also point to something more complex.

Honors and awards generally do not begin to accrue until after the 14th year of a scientific career. This suggests that part of the explanation for the differential reward system is related to differences in career length.

Quantitative data indicate gender-specific differentials in the distribution of honors and awards in American astronomy. As Robert S. Richardson of the Mount Wilson Observatory wrote in the 1940s, "Scientific societies being composed entirely of men, have been notoriously reluctant . . . to accord recognition to women." Before 1940 four women held a total of six elected offices in astronomy-related scientific societies. This stands in sharp contrast to the 403 elective offices held by male astronomers. Two women and 164 men served in various editorial positions on astronomy and astronomy-related scientific journals. Before World War II, three female and 76 male astronomers were elected to the American Philosophical Society. The American Academy of Arts and Sciences and the National Academy of Sciences did not elect any female astronomers in these years.

While archival data are incomplete, attempts of the astronomy section of the National Academy of Sciences to nominate a woman for membership in the academy make a compelling story. Florence Sabin, a physiologist at of the Rockefeller Institute, became the first woman member of the academy in 1925, followed by Vassar psychologist Margaret Floy Washburn in 1931. In 1944 geneticist Barbara McClintock became the third female academician. The astronomy section, however, remained a men's club until 1978.

In 1923 Raymond Pearl of Johns Hopkins and Edwin B. Wilson of Harvard, two of the behind-the-scenes powers in the academy, discussed the question of electing Harvard Observatory spectroscopist Annie Jump Cannon. Apparently, Wilson raised the subject first. It is clear from the correspondence that Wilson favored recognizing the achievements of distinguished women scientists. Indeed, he worked for their election to the American Academy of Arts and Sciences, but without success. Pearl's reaction was complex. He may have wanted to help Sabin's candidacy by using Cannon as a stalking-horse.

Wilson supported the Wellesley-trained Cannon for National Academy membership because of her work on the Draper catalog of stellar spectra, a project that occupied Cannon for 40 years. "I don't see much difference in looking at a photograph and looking at the original star," Wilson wrote. "I don't believe [Henry Norris] Russell could have done his work [on stellar evolution] if he hadn't had the Draper catalogue to use."

Two years later Harvard Observatory director Harlow Shapley tried to interest members of the astronomy section in nominating Cannon. He was astonished to learn, he wrote in a letter to Wilson, that Russell and Schlesinger "did not specially favor the candidacy of Miss Cannon." Shapley further noted that "their reason seems to be that present interpretative ability rather than past accomplishment should count." Shapley felt extremely frustrated by the negative responses from Schlesinger and Russell. He told Wilson that "one European astronomer of recognized standing told me this summer that as seen from Europe, Miss Cannon would rank above half a dozen of the present astronomical members of the Academy." He did succeed in bringing Cannon's name before the section, but surviving records indicate she received little support. Perhaps Cannon looked upon her 1925 honorary degree from Oxford as a consolation prize. It was a mark of major international recognition, reserved for only a few American scientists in any generation.

The saga of the attempts to elect British-born Cecilia Payne-Gaposchkin, the first person to receive a PhD from the Harvard astronomy department, is far more complicated. Payne-Gaposchkin first appeared on the list of potential nominees in the fall of 1929, and in 1931 she received two votes on the preliminary ballot. Apparently she remained before the section for several years, but the next available documents list her with still only two votes in the informal balloting of 1935. This number grew to four in 1936. In 1939 Payne-Gaposchkin was the section's nominee, with a total of 17 votes. At the April academy meetings in both 1940 and 1941, the balloting was closed before her name could be presented. In 1942 she was again nominated, receiving 14 votes to Donald Menzel's 13, but in 1943 the academy rejected her for membership. Before World War II, only one male astronomer had ever been rejected by the academy at its April meeting, and in that case he was renominated and subsequently elected.

Given the paucity of archival material, it is impossible to tell just why Payne-Gaposchkin was rejected. A clue, however, exists in the Shapley manuscripts at Harvard. In the fall of 1940, Frederick Wright, the academy's home secretary, wrote Shapley concerning materials supplied in support of the nomination. These materials, traditionally a select bibliography and brief biography prepared by a member of the section making the nomination, were criticized by Wright as "laudatory." The home secretary lectured the Harvard Observatory director, "Admittedly, the distinction between matters of laudatory opinion and conclusions of fact is often very closely drawn, but an impartial observance of the spirit as well as the letter of the bylaws requires that there be no departure from strict statements of fact." The offending sentence in the material supplied by Shapley read as follows: "Her programs in stellar photometry are probably more extensive than those of any other astrophotometrist."

Wright did not inform Shapley of the names of members who complained, and we can find no reference to this matter in other manuscript collections. It is true, however, that in that earlier epoch, when men were

Caroline Furness at Vassar, around 1920. As a college senior in 1891 Furness wrote to her father to argue for her further education: "I only want to prepare myself for the highest place—just as any young man might. . . . I want to prepare myself to live a useful and happy life without marriage, and then, if the right one comes along, well and good, I shall take him, but I shall not be obliged to take a man just for the sake of a home. . . . If I were your son instead of your daughter, you would fully approve of my ambition." (Photo courtesy of Gingerich.)

extremely sensitive to claims for recognition for women, female candidates were scrutinized in almost pathological detail.

American astronomy owes much to women workers. Its rise to world-class status after 1900 could not have been achieved without them. Their roles, however, were almost always subordinate to those of men. The roots of this inequality go deep into astronomy's past. These findings are not to be taken as counsels to despair, although the policy implications are sobering. More than goodwill and optimistic rhetoric is required to effect change. A century and a half of inequality cannot be wished away, but will disappear as the result of structural, demographic and political changes. Perhaps the next generation will see women gain full equality in astronomy and the other physical sciences as well.

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Primary sources

Archives and manuscript collections provide an intellectual time machine that can take one back to earlier epochs in the history of science. Many of the letters, diaries, memoranda and observing books on which this article is based come from such collections.

On the West Coast, the Bancroft Library at the University of California, Berkeley, houses the papers of that campus's astronomy department, the largest producer of astronomy PhDs before World War II. The Mary Shane Archives of the Lick Observatory are on the University of California, Santa Cruz campus and contain a wealth of historical treasures.

In the Midwest, the archives of the Yerkes Observatory at Williams Bay, Wisconsin, and the papers of the directors of the Washburn Observatory, in the archives of the University of Wisconsin, Madison, were indispensable. There are a few choice items on Maria Mitchell in the C. H. Davis papers at the Ford Museum and Library, in Dearborn, Michigan.

Moving further east, the archives at Vassar and Wellesley were of great value; the former contains the papers of Mitchell and Caroline Furness, and the latter the Sarah Frances Whiting manuscripts. The Harvard archives hold the Harlow Shapley papers. The Yale University archives contain the records of the astronomy department there and the papers of Yale astronomers. The archives of the National Academy of Sciences, in Washington, DC, also contain important resources.

From archival and printed sources such as biographies and obituaries, we collected data on the backgrounds, education, careers and research activities of 1205 individuals who worked full time in the American astronomical community between 1859 and 1940. These data were converted to a computer database to provide a resource for studying the astronomical community over that time period. Quantitative material discussed in this article is drawn from this database.

Further reading

Margaret W. Rossiter's *Women Scientists in America: Struggles and Strategies to 1940* (Johns Hopkins U. P., Baltimore, 1982) is the place to begin. It should be supplemented by Pnina G. Abir-Am and Dorinda Outram, eds., *Uneasy Careers and Intimate Lives: Women in Science, 1789–1979* (Rutgers U. P., New Brunswick, N. J., 1987).

Cecilia Payne-Gaposchkin: An Autobiography and Other Recollections (Cambridge U. P., Cambridge, England, 1984) was edited by her daughter, Katherine Haramundanis.

Sex Segregation in the Workplace: Trends, Explanations, Remedies (Nat. Acad. of Sci., Washington, 1984) was edited by sociologist Barbara F. Reskin and provides a good introduction.

Robert L. Heilbroner and Aaron Singer deal with *The Economic Transformation of America* (Harcourt Brace, New York, 1984), stressing the importance of the factory in America at the end of the 19th century. Lankford's own work in progress, *Change and Continuity in a Modern Scientific Community: American Astronomy, 1859–1940* contains an extended discussion of the ways in which practices in the business sector affected astronomy.

Historian Barbara Welter introduced the concept of separate spheres in a path-breaking paper, "The Cult of True Womanhood, 1820–1860," *American Quarterly* **8**, 151 (1966). It should be supplemented by Rosalind Rosenberg's *Beyond Separate Spheres: Intellectual Roots of Modern Feminism* (Yale U. P., New Haven, Conn., 1982). Helen Wright's *Sweeper in the Sky: The Life of Maria Mitchell, First Woman Astronomer in America* (Macmillan, New York, 1950) is useful, but for biographical material on other women scientists readers must turn to Edward T. James, ed., *Notable American Women, 1607–1950* (three volumes, Harvard U. P., Cambridge, Mass., 1971) or to obituaries. ■