DOCUMENT RESUME

ED 360 166 SE 053 545

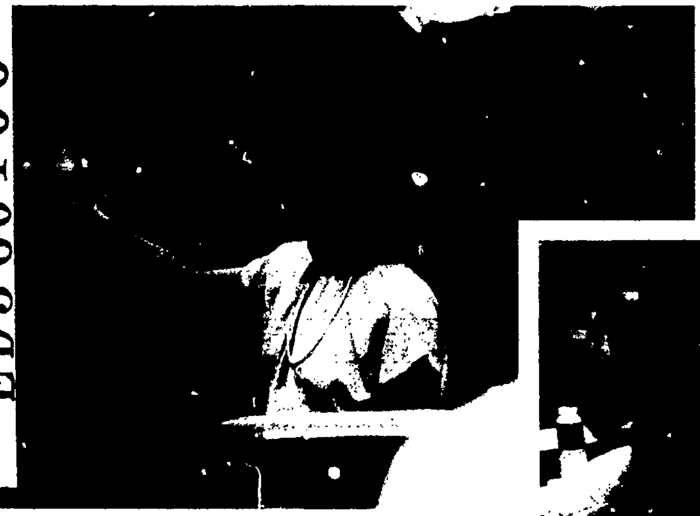
TITLE	Women in Astronomy.
INSTITUTION	Astronomical Society of the Pacific, San Francisco, CA.
REPORT NO	ISSN-0047-6773
PUB DATE	92
NOTE	51p.; Special theme issue on "Women in Astronomy."
AVAILABLE FROM	Astronomical Society of the Pacific, Mercury Sales Dept., 390 Ashton Ave., San Francisco, CA 94112 ($5).
PUB TYPE	Collected Works - Serials (022)
JOURNAL CIT	Mercury; v21 n1 spec iss Jan-Feb 1992
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	*Astronomy; Elementary Secondary Education; Employed Women; *Females; Higher Education; Physical Sciences; *Science Education; *Scientists; Sex Bias; *Sex Fairness; Sex Role; Solar System; Space Exploration; *Space Sciences

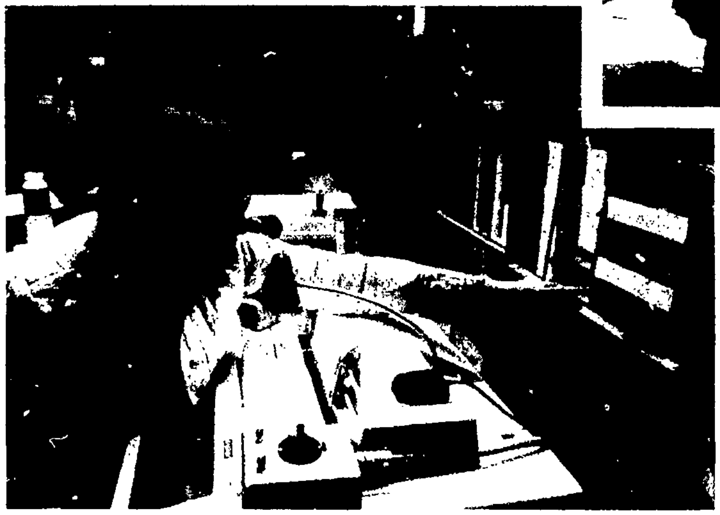
ABSTRACT

This issue of "Mercury" is a tribute to the accomplishments of female astronomers. It is an affirmation that women can and do pursue successful careers in the physical sciences even though some special obstacles have existed and, sadly, continue to exist in both the education process and the professional career process. The journal contains the following articles: (1) "A Historical Introduction to Women in Astronomy" (A. K. Dobson and K. Bracher); (2) "Some Glimpses from My Career" (D. Hoffleit); (3) "Henrietta Hill Swope: Variable Stars in the Milky Way and Andromeda" (B. L. Welther); (4) "One Woman's Journey" (A. M. Boesgaard); (5) "Shortchanging Girls" (N. Barlow); (6) "Discrimination in the Workplace: Results of Two Recent Surveys and Some Recommendations" (J. Price); (7) "A Male Perspective: Not Equal, Not Yet" (G. Clayton); (8) "Women Worldwide in Astronomy" (D. Hunter and V. Rubin); (9) "Forming a Local Women-In-Astronomy Group" (E. M. Alvarez del Castillo); (10) "Vera Rubin: An Unconventional Career" (S. Stephens); and (11) "Women in Astronomy: A Bibliography" (A. Fraknoi and R. Freitag). (PR)

MERCURY

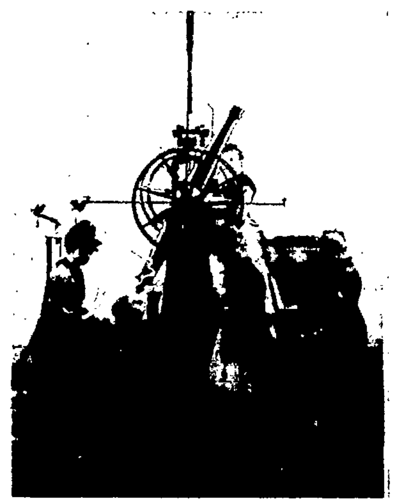
The Journal of the Astronomical Society of the Pacific
Vol. XXI, Number 1 • January/February 1992

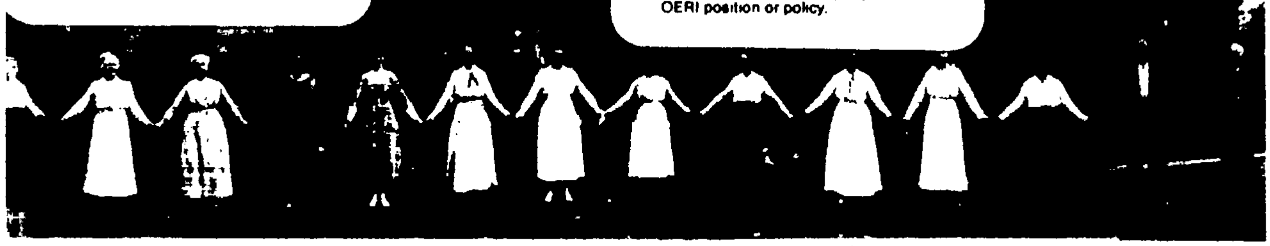




Special issue:

Women in Astronomy



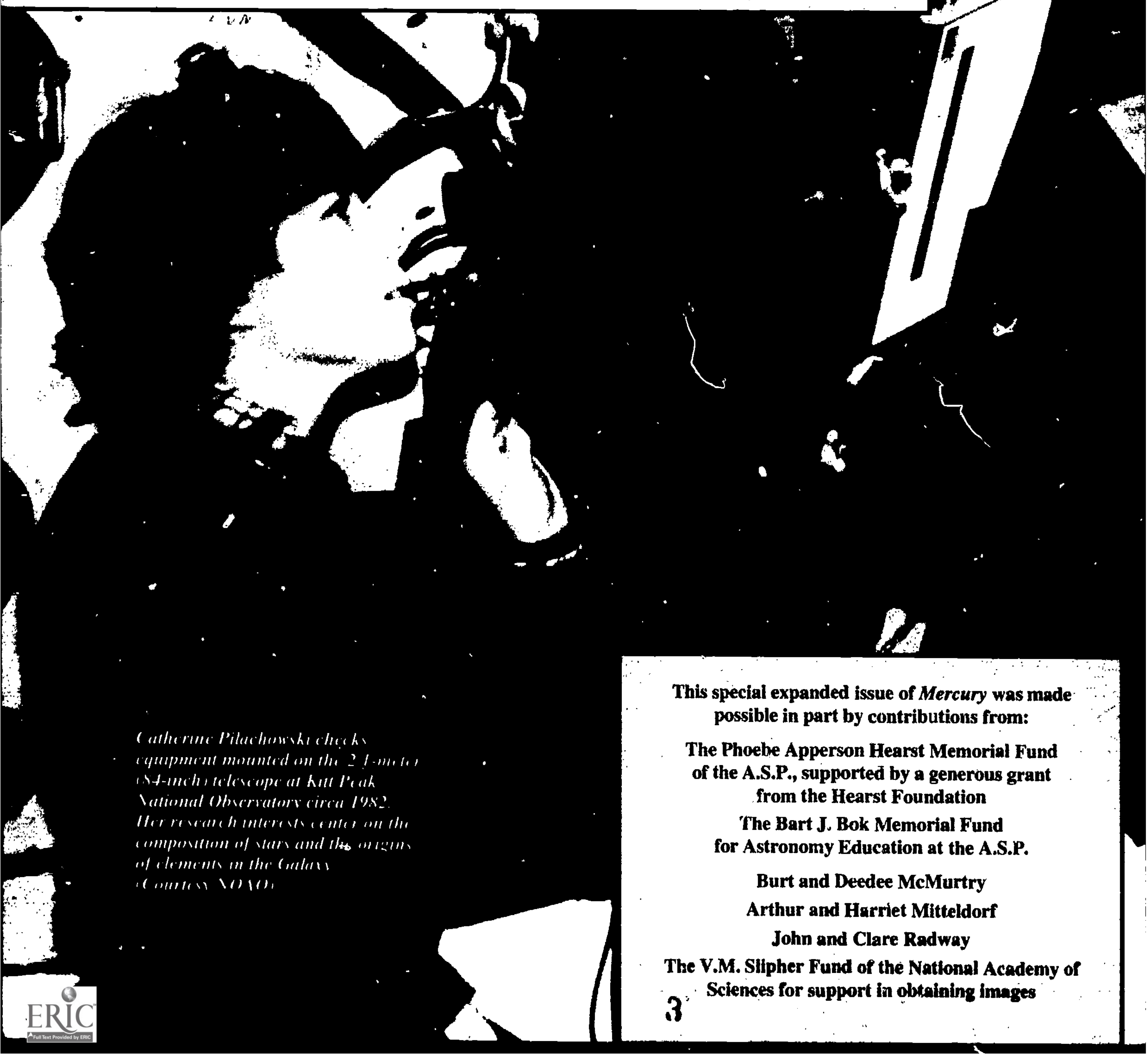


From the Editors:

Welcome to this special issue of *Mercury* magazine dedicated to women in astronomy. In preparing this issue, we sent a questionnaire to a representative group of astronomers, both female and male. We asked for their opinions about the current status of women in astronomy and for personal reminiscences of life as an astronomer. The survey was intended to bring as wide a diversity of opinion as possible to this issue. A sampling of some of the responses we received begins on page 27.

We also asked how each person became interested in astronomy. A surprising number of women told of being interested in science as a girl, but thinking that it was not something women could do, or something that only a few women in history, like Marie Curie, did. It was only when they read about, or met living women astronomers that they realized that they too could pursue their dream. This issue is intended to showcase the accomplishments of women in astronomy, while not ignoring the problems they faced (and continue to face). Perhaps the women within these pages will inspire yet another generation of women to pursue their dreams of studying galaxies and stars.

Sally Stephens* and *Andrew Fraknoi



Catherine Pilachowski checks equipment mounted on the 2.1-meter (84-inch) telescope at Kitt Peak National Observatory circa 1982. Her research interests center on the composition of stars and the origins of elements in the Galaxy. (Courtesy NOAO)

This special expanded issue of *Mercury* was made possible in part by contributions from:

The Phoebe Apperson Hearst Memorial Fund of the A.S.P., supported by a generous grant from the Hearst Foundation

The Bart J. Bok Memorial Fund for Astronomy Education at the A.S.P.

Burt and Deedee McMurtry

Arthur and Harriet Mitteldorf

John and Clare Radway

The V.M. Slipher Fund of the National Academy of Sciences for support in obtaining images

TO: ***MERCURY*** Readers

FROM: Julie Lutz, A.S.P. President

This issue of *Mercury* is a tribute to the accomplishments of female astronomers. It is an affirmation that women can and do pursue successful careers in the physical sciences even though some special obstacles have existed and, sadly, continue to exist. I'm pleased that the issue has so many positive images of women astronomers. Over the years, I have seen my female colleagues show a great deal of tenacity, courage, and humor in their careers and their lives, and you can see these attitudes reflected in the articles and thoughts they have contributed to the pages that follow.

Frankly, I'm not sure that women astronomers will ever be on an entirely level playing field with their male colleagues. However, I do believe that now is a good time to get out the bulldozers and try to make that playing field as flat as possible. The population of female graduate students in astronomy has grown to 20 percent of the total. A considerable number of women astronomers have joined the ranks of Associate and Full professors. Women currently occupy the positions of President of the A.S.P., President-Elect of the American Astronomical Society, Director of the Division of Astronomical Sciences and Chair of the Advisory Committee for Astronomical Sciences at the National Science Foundation, and Director of the National Optical Astronomy Observatories. Sexual harassment, affirmative action, family leave, and child care are significant issues on university campuses and elsewhere, and are being talked about more openly than ever before. Change is in the air, but it won't happen if people who are interested in equal opportunity don't push.

I have seen women astronomers experience problems that most male astronomers can only imagine. I and my female colleagues have experienced things like unwanted sexual advances, discouragement by peers and superiors that has a gender-based content, being marginalized and demeaned, and other behaviors that are deleterious to our full participation in the science we love. It's time that no woman should have to put up with that stuff!

What should we do? I'm action oriented, so here are some suggestions:

1. If you are in a situation where you think discrimination is occurring, take action. Taking action empowers you.
2. More discussions of these issues couldn't hurt. Sometimes people honestly don't realize that their behavior is not appropriate, and they change when the matter is brought to their attention directly or indirectly.
3. We should all take to heart the feminist slogan "Sisterhood is Powerful." It is. Networking and mentoring are crucial for women.
4. Senior astronomers, male as well as female, must be aware of problems and actively receptive to change. Sitting on the sidelines won't do.

I'm optimistic about having more women pursue careers in astronomy. I've always maintained that, since half the brains in the world belong to women, 50 percent of astronomers should be women. On that happy note, let me raise the curtain on this special edition of *Mercury*.

Additional copies of this issue are available for $5 postpaid from: A.S.P., *Mercury* Sales Dept., 390 Ashton Ave., San Francisco, CA 94112. Outside the U.S. add $2 for postage and remit in U.S. funds.

Urania's

A Historical ... to Women in

Author's note: **Urania was the ancient Greeks' Muse of Astronomy.**

Andrea K. Dobson
Whitman

"Women astronomers" must seem like an oxymoron to many. Pick up any current textbook on astronomy (nearly all of which are written by men[1]) and examine the index: among the couple of hundred people listed, chances are good that you will find fewer than six or seven women. Is it actually the case that astronomy (or at least "significant" astronomy) is and has been done only by men? Hardly. Despite often intimidating social pressures, women have always participated in astronomy. Many women, whose names our students by and large don't find in their textbooks, have made valuable contributions to our deepening understanding of our universe.

The opportunities for women to participate in astronomy (and, of course, in the sciences generally) have been constrained both by external pressures such as lack of access to education (and lack of access to work and equipment even with education), and by social conditioning that led many brilliant women to question their own worth and abilities. In this article, we want to look briefly at the work of several women astronomers and also at how the opportunities, work, and self-images of women in astronomy have changed over the past two centuries.[2]

1. A significant exception is former A.S.P President and the Director of the National Optical Astronomy Observatories Sidney Wolff. She is the co-author, with David Morrison, of a series of textbooks, including those first begun years ago by the late George Abell. — *Ed.*

2. For more on the work of the women mentioned in this article, and many others, see the bibliography later in this issue. — *Ed.*

MERCURY — The Journal of the Astronomical Society of the Pacific (ISSN 0047-6773) is published bimonthly by the Astronomical Society of the Pacific, 390 Ashton Ave., San Francisco, CA 94112. Yearly subscription rate is

Heritage:

Introduction Astronomy

Katherine Bracher
College

Caroline Lucretia Herschel

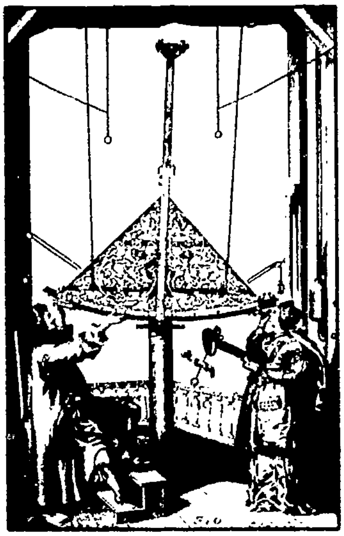
Before the widespread accessibility of higher education it was often the case that women (and men, a point that is often overlooked) came to an interest in astronomy by way of a relative. Often women astronomers were assistants to their fathers, husbands, or brothers; such collaboration makes it all too easy to label their work as not particularly original.

One who received some amount of recognition for her assistance was Caroline Lucretia Herschel, born in 1750 in Hanover into a large and musically inclined family. Her mother deemed it appropriate that Caroline receive a minor amount of formal education and a large amount of informal training to equip her to care for her brothers. Her brother William, 12 years her senior, took his musical training and his interest in astronomy to England in 1757; Caroline followed him 15 years later. With some additional formal training Caroline Herschel probably could have pursued an independent singing career; she preferred to give that up to assist and keep house for William.

William's 1781 discovery of Uranus (and the ensuing salary bestowed upon him by King George III) allowed him to devote his time entirely to astronomy. While William ground the glass for his telescopes, Caroline fed him by hand; while he observed, she recorded his observations. In 1782 he gave her a small telescope with which she could observe the skies on her own when he was away. On August 1, 1786, Caroline discovered a comet, the first of eight she found over a span of eleven years. Her note to the Secretary of the Royal Society announcing her first discovery is almost apologetic in tone; later announcements are more professional and less self-deprecating.

$29.50 within the U.S. and $37.50 foreign. Second class postage paid at San Francisco and at additional mailing offices. POSTMASTER: Send address changes to: ***Mercury,*** A.S.P., 390 Ashton Ave., San Francisco, CA 94112.

A Few Women Astronomers before Caroline Herschel



Catherina Elizabetha Hevelius (1646-1693) (also known as Elizabeth Margarethe) was the second wife of the famous Polish astronomer Johannes Hevelius. Unable to find a reliable aide for his observations, he trained his wife to act as his assistant. Together they made nightly observations for a catalog of fixed stars. Unfortunately much of their work was destroyed by a fire in 1679. When Hevelius died in 1687, his wife continued his research. She published two catalogs, *Prodromus Astronomiae* and *Firmamentum Sobiescianum*, the latter of which contained 1,564 stars, the largest and last catalog made without the aid of a telescope.

Nicole-Reine Lepaute (1723-1788) was well known for her extraordinary mathematical abilities. The French astronomers Clairaut and Lalande sought her help for the difficult computations needed to predict the path of Halley's Comet. For six months the trio frantically calculated the movements of Jupiter and Saturn over 150 years to find their effects on the comet, successfully predicting the date of its return in 1757. Lepaute's computations for the annular eclipse of 1764 were used throughout Europe. Unfortunately, her years of arduous calculations left her nearly blind.

Margaret Bryan (17[?] - 18[?]) was a British natural philosopher and a teacher in a seminary for girls. In 1797, she published *A Compendious System of Astronomy, In A Course of Familiar Lectures,* a widely used textbook for students not previously acquainted with advanced mathematics. She also published *Lectures on Natural Philosophy* in 1806, and *Astronomical and Geographical Class-Book* in 1815. Although not widely remembered, she combined a teaching and writing career with bringing up two daughters.

Maria Gaetana Agnesi (1718-1799) was a leading mathematician in the Newtonian period. In 1738, she published a treatise on universal gravitation, hydromechanics and celestial mechanics. A mathematical curve is named after her.

Illustrations and text from IBM's 1975 "Women in Astronomy" exhibit; courtesy Griffith Observatory

For her work, the king granted Caroline Herschel an annual pension of 50 pounds, the "first time that a woman had been appointed assistant to the court astronomer." It was also the first time Caroline had ever had any funds of her own to use as she wished. William married in 1788, freeing Caroline from the duties of a housewife. She continued to assist him in his astronomy, however, and to make her own observations as time permitted.

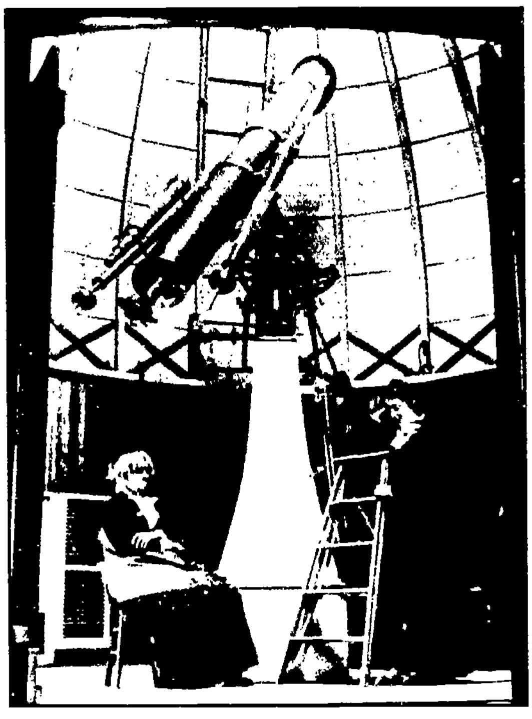
More significant than her comet discoveries was Herschel's work in the reduction and publication of her brother's observations of nebulae. The reduction of position measurements to a common epoch was, to put it mildly, a tedious business. Her publications included, following William's death in 1822, *A Catalogue of the Nebulae Which Have Been Observed by William Herschel in a Series of Sweeps*, containing over 2500 positions. For this work Caroline, who had returned to Hanover, received in 1828 a Gold Medal from the Royal Astronomical Society (RAS). William's son John, also a noted astronomer, was president of the RAS at the time and seems to have been quite ambivalent about the award. In writing to notify his aunt, John says "Pray let me be well understood on one point. It was none of my doings. I resisted strenuously. Indeed, being in the situation I actually hold, I could do no otherwise. The Society have done well. I think they might have done better, but my voice was neither asked nor listened to." (In subsequent correspondence he does apologize for offending his aunt.) Caroline was a bit unsure of the matter herself, writing in reply to her nephew that "I felt from the first more shocked than gratified by that singular distinction, for I know too well how dangerous it is for women to draw too much notice on themselves . . . Whoever says too much of me says too little of your father!" Throughout her life she consistently down-played her own work in favor of her brother's.

Herschel kept up, as best she could with failing eyesight, with current astronomy, and frequently received visiting scientists passing through Hanover. In 1835 she and Mary Somerville were elected honorary fellows of the RAS (women, of course, not being permitted to be actual members), and on the occasion of her birthday in 1846 she received a Gold Medal for Science from the King of Prussia. She died the following year at age 97.

The gold medal awarded to Maria Mitchell for the discovery of a telescopic comet in 1847 from the King of Denmark. (Photo by Fred Clow, courtesy Maria Mitchell Association)

Maria Mitchell

In the year of Herschel's death a comet was found by a 29-year-old librarian and amateur astronomer. For this discovery Maria Mitchell was awarded a gold medal by the King of Denmark, offered for the first report of a comet that was not visible to the naked eye at the time of its discovery. This catapulted her to a considerable amount of fame, although not so lasting that the Smithsonian Institution felt inclined to include Mitchell in its 1976 exhibition on 200 years of American astronomy.



Maria Mitchell (left, 1818-1889) with a student at the Vassar College Observatory. (Courtesy Vassar College Library)

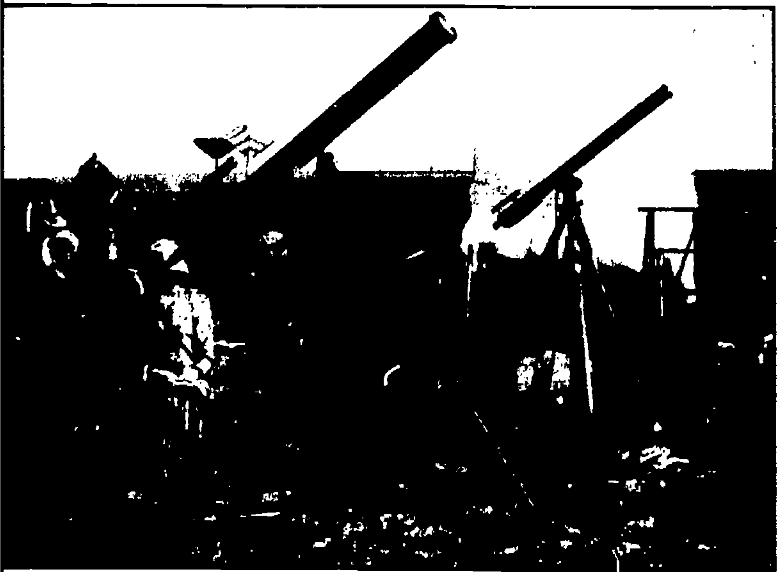
Mitchell was born in 1818 to a Quaker family on the island of Nantucket. With many of the local men away at sea for long periods, the island women were of necessity quite reliant upon each other, which may have influenced Mitchell's later belief in the work of women's colleges. Her father was interested in astronomy and Maria assisted him, learning to use a sextant and set a chronometer at an early age. Her later assessment of her own abilities was that she "was born of only ordinary capacity, but of extraordinary persistency". Mitchell's formal schooling came to an end when she was 16. After teaching for about a year, Mitchell was offered the post of librarian at the new Nantucket Atheneum. Since the Atheneum was only open afternoons and Saturday evenings, Mitchell had plenty of time for study and astronomy. Her father's recognition as a good amateur astronomer brought Maria into contact with professional astronomers at places like Harvard and the Smithsonian.

Following Mitchell's comet discovery, she was elected as the first woman member of the American Academy of Arts and Sciences (in 1848 — it would be 95 years before a second was elected) and to the newly formed American Association for the Advancement of Science (1850). In 1849 Mitchell was employed as a computer (one who performs lengthy mathematical calculations) for the American Ephemeris and Nautical Almanac, calculating positions of the planet Venus; she continued at this occupation for 19 years.

Mitchell's greatest contributions came in the area of women's education. While her comet discovery was not exactly earth-shattering science, it had brought Mitchell recognition as one of a very few women scientists in the U.S. Thus, in 1865, when Vassar College opened, Mitchell was asked, despite her lack of formal education, to become professor of astronomy and director of the observatory. At this point, concerned about the "half-educated, loose, and inaccurate ways" in which young women seemed to think, Mitchell seems to have made a conscious decision to commit her time to teaching rather than to more prestigious research work. And apparently as a teacher Mitchell was outstanding, highly motivating, and demanded painstaking mathematics and careful observations. The Vassar trustees certainly weren't convinced of her worth: Mitchell received a salary of $800, compared to the $2500 received by the male professors.

Despite a lack of good equipment, Mitchell and her students were able to do productive astronomy. She observed several solar eclipses, including the notable eclipse of 1878, for which she traveled to Denver; she followed the changes in sunspots; her regular observations of Jupiter led her to conclude that one sees merely the uppermost clouds of a body composed entirely of clouds, rather than thin clouds above a solid surface as was supposed by current theory; she noted also the differences in appearance among Jupiter's satellites. For her work Mitchell received three honorary degrees: LL.D.'s from Hanover College (1853) and Columbia (1887) and a Ph.D. from Rutgers (1870). She is also honored by a small lunar crater which bears her name.

Over the course of her life Mitchell became more and more



Maria Mitchell (left) and six of her students traveled to Burlington, Iowa to witness a total eclipse of the Sun on August 7, 1869. (Courtesy Vassar College Library)

interested in the cause of women's rights generally and women's science education more specifically. In 1873 she helped found the Association for the Advancement of Women, and served as president of that organization for two years, 1875 and 1876. She chaired the AAW science committee until her death.

Mitchell recognized that her work did not produce incredible advances in theoretical astronomy. She strenuously objected, however, to the suggestion that as women had patently contributed so little to science in the past, they were therefore incapable of doing so in the future. To compare the work, for instance, of Caroline Herschel, busy knitting her brother's socks, to that of Tycho Brahe, provided with an observatory and assistants, was simply not fair: "The laws of nature are not discovered by accident, theories do not come by chance, even to the greatest minds; they are not born of the hurry and worry of daily toil; they are diligently sought . . . And until able women have given their lives to investigation, it is idle to discuss their capacity for original work." Mitchell, however, felt that there were some areas of research where women might particularly excel: specifically those requiring painstaking measurement and attention to detail.

The Role of Women's Colleges

Maria Mitchell saw the end of the era when astronomy was done by lone, reasonably well-off amateurs. Advances in technology — photography, spectroscopy, larger telescopes — soon led to a rise in the number of observatories and a rise in the cost of doing astronomy. Formal education came to be a necessity, and learned societies began distinguishing the professional scientists from the self-taught amateurs. (And of course, women, being *ipso facto* amateurs, were therefore not welcome!)

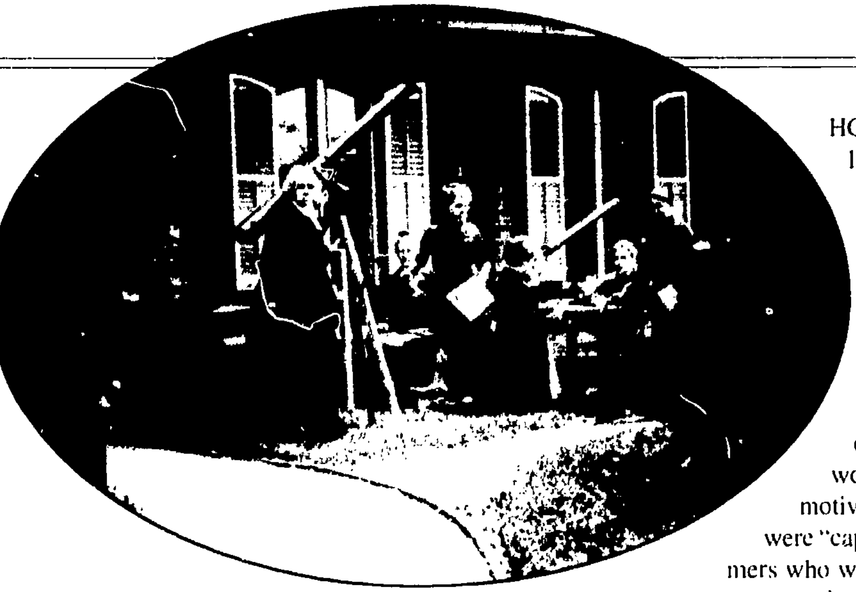
As the end of the nineteenth century approached, the availability of higher education for women increased dramatically. At the fore in the U.S. were the women's colleges: in addition to Vassar, there were Mt. Holyoke (founded in 1837), Smith (1871), and Wellesley (1875), to name some of the earliest. Graduate education, a new-fangled idea of the men's universities, was still fairly hard to come by. Winnifred Edgerton, who graduated from Wellesley in 1883, fought long and hard to be allowed to attend Columbia University, where she earned the first Ph.D. in astronomy by an American woman in 1886; she was followed by four more women in the 1890s.

An education was of course no guarantee of a job. Dorothea Klumpke — who later set up an endowment at the A.S.P. — earned her doctorate and a position in Paris; Margaretta Palmer (Ph.D. 1894) stayed on as a computer at Yale. The women's colleges were a small exception: 16 women found work as professors and/or observatory directors at Vassar, Mt. Holyoke, Smith, Wellesley, and co-ed Swarthmore between 1865 and 1926. In some cases this resulted in a chain of women several generations long: at Vassar, Maria Mitchell was succeeded by Mary Whitney, one of her first students, who in turn was succeeded by Caroline Furness, Vassar class of 1891.

The research done at the women's colleges tended to be similar to Mitchell's early program at Vassar: patient, repetitive observation of objects such as comets, asteroids, variable stars. As Pamela Mack has noted, "The professors at the women's colleges chose research problems in the areas stereotyped as women's work because those topics could be pursued with the equipment they had available and because male astronomers they consulted about their research programs suggested those topics." The rigorousness of their course work does not seem to have been below the standards of the men's schools, though. The second student physics laboratory in the U.S., for instance, was established at Wellesley (where physics was required of all students!) in the late 1870s under Sarah F. Whiting, with advice from Edward C. Pickering who had recently designed the first such laboratory at MIT.

In 1886, Winnifred Edgerton (1862-1951) became the first American woman to receive a Ph.D. in astronomy (from Columbia University). After graduation, she married and, partly at her husband's insistence, traded in academic life for family life. Edgerton maintained an interest in women's education, however, founding the Oakesmere School for Girls in Greenwich, Connecticut in 1906.

(Photo by Pach Brothers, courtesy Wellesley College Archives)



Maria Mitchell (second from left) at Vassar College, with her students, circa 1878. (Courtesy Vassar College Library)

HCO two years later, and between then and his death in 1919,HCO employed 45 women, more than any other observatory. While Pickering encouraged bright young women to pursue higher education, he, along with most other scientific men of the time, believed that the intellectual abilities of women suited them for repetitive, non-creative data-gathering projects, not for original theoretical work.

Pickering was an early proponent of the growing science of astrophysics and a Baconian collector of data. He seems to have been supportive of women working in astronomy, but also highly economically motivated: in his 1898 annual report, he noted that women were "capable of doing as much good routine work as astronomers who would receive larger salaries. Three or four times as many assistants can thus be employed." The women at HCO usually received between 25 and 35 cents per hour. In a time of

The Observatories

The new generation of college-educated women astronomers found some chances for employment as computers at the larger observatories. Vera Rubin relates a comment by one of her graduate students to the effect that the rapid rise of U.S. astronomy in the early 20th century was due to the fact that George Ellery Hale (builder of large telescopes) discovered money and Edward C. Pickering discovered women! Pamela Mack has found records of 164 women who worked for various U.S. observatories between 1875 and 1920. The Harvard College Observatory (HCO) hired its first women assistants in 1875. Pickering became director of the

A group of staff members at the Harvard College Observatory in 1925. Left to right: Harvia H. Wilson, Agnes M. Hoovens, Antonia C. Maury, Ida E. Woods, Annie J. Cannon, Mary Howe, Margaret Harwood, Evelyn F. Leland, Arville D. Walker, Lillian L. Hodgedon, Cecilia H. Payne, Edith F. Gill, Margaret L. Walton, Mabel A. Gill, and Florence Cushman. (Courtesy Harvard College Observatory)

Edward C. Pickering, as Director of the Harvard College Observatory, hired many women to work as human computers, calculating positions and orbits of astronomical objects and classifying thousands of stars. (Courtesy Yale University)

severely restricted opportunities, Pickering had applications from far more women than he could possibly employ. The women had no hope of advancing to positions where they might design independent research projects. Their tasks were of the type expected of women: many spent decades recording, cataloging, and classifying. In part because of the time spent and, hence, their extreme familiarity with their subjects, many produced extremely valuable work. (It was a reflection of the times that the group of women working at Harvard were nicknamed "Pickering's Harem.")

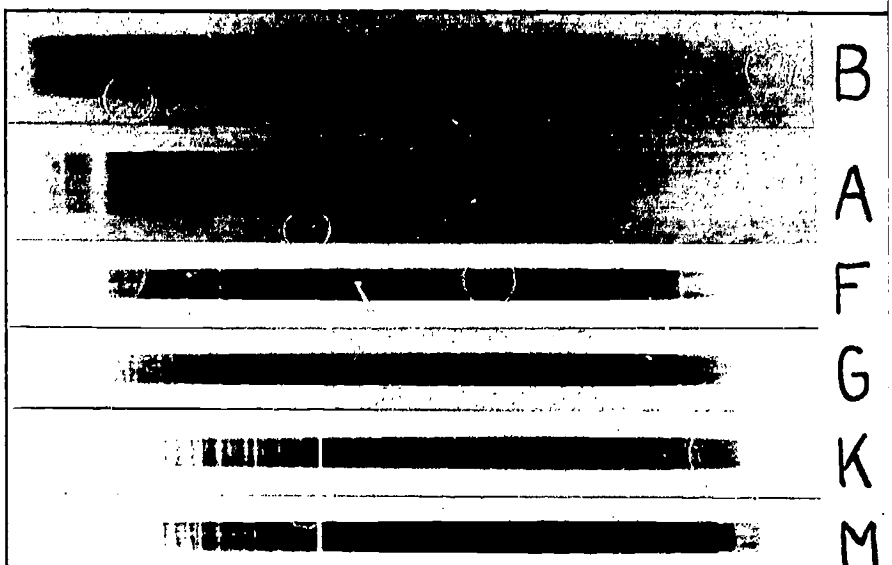
A group of women computers, directed by Williamina Fleming (standing). The seated figure in the front is Evelyn Leland; at the left rear is Antonia Maury. Circa 1890. (Courtesy Harvard College Observatory)

Fleming was succeeded as Curator of Astronomical Photographs (although not by Corporation appointment) by Annie Jump Cannon, Wellesley class of 1884. Cannon was born in 1863 into a fairly well-to-do family; her mother was an amateur astronomer and sparked her interest in the sky. Studying at Wellesley under Whiting, Cannon developed an interest in spectroscopy. Following her graduation, Cannon dutifully spent a decade at home with her parents in Delaware, "very dissatisfied with life... [because there] are so many things that I could do". Cannon returned to Wellesley as a physics assistant following her mother's death in 1894. She took astronomy classes at Radcliffe and in 1896 joined the staff at HCO.

Cannon rearranged Fleming's spectral classification system to reflect systematic trends in the strengths of all spectral lines, not merely those of hydrogen. This meant dropping some of Fleming's letter classes and reordering others. The result is the OBAFGKM series of spectral types, reflecting decreasing stellar surface temperature, that is still (with minor modifications) in use today.[4] Following her appointment as Curator of the photographic collection, Cannon began a systematic classification of all stars on all Harvard photographic plates down to 9th magnitude. In all, she examined and classified nearly 500,000

Fleming and Cannon

One of the first women hired by Pickering was Williamina Paton Fleming. Fleming was born in Scotland in 1857. She and her husband emigrated to the U.S. in 1875. When their marriage disintegrated two years later, leaving her pregnant, Fleming found employment as a maid with Pickering. By 1881 she was working at the observatory, initially doing fairly routine projects. With time her responsibilities increased. Studying photographic spectra, Fleming discovered 94 of the 107 Wolf-Rayet stars[3] known at the time of her death, 10 of the 28 known novae, and 222 long-period variable stars; she edited observatory publications and became supervisor of the increasing number of women assistants. The bulk of the first Henry Draper catalogue of stellar spectral types was based on her classifications. (Henry Draper was a well-to-do New York physician and amateur astronomer; his widow donated a considerable amount of money to the Harvard observatory in his memory.) In 1898 Fleming was given a Harvard Corporation appointment as Curator of Astronomical Photographs, the first such appointment made to a woman. In 1906 she was elected an honorary member of England's Royal Astronomical Society. In addition to her career, she successfully raised her son Edward and put him through MIT. Fleming seems to have subscribed to the idea of a "woman's place" in the observatory: she spoke at the 1893 Chicago World's Fair on "A Field for Women's Work in Astronomy," valuable despite its restrictions. Fleming died in 1911 at the age of 54.



The OBAFGKM spectral sequence, pioneered by Annie Jump Cannon, classifies stars according to the lines in their spectra. In this negative image, the spectral class is listed to the left of each spectrum. B, A and F stars show primarily spectral lines from hydrogen and helium, whereas K and M stars have strong lines from calcium and titanium oxide. (Courtesy Yerkes Observatory)

3. Wolf-Rayet stars are now known to be hot, bright, massive stars that are ejecting a shell of material; novae are stars that show a sudden outburst of radiation. — *Ed.*

Annie Jump Cannon (1863-1941), in her later years, at work examining a photographic plate. (Courtesy Harvard College Observatory)

spectra. In sparse regions, she could classify at a rate of better than three stars per minute, calling out her observations to an assistant. Her classifications were accurate to 1/10 of a spectral type (determined years later when Cannon reclassified a number of spectra). Her work was published as the nine-volume Henry Draper Catalogue between 1918 and 1924.

In recognition of her contributions to astronomy, Cannon received six honorary degrees, including one in 1925 from Oxford. She was elected to the RAS in 1914. In 1932 she received the Ellen Richards Research Prize, awarded by the Association to Aid Scientific Research by Women. This latter included a cash award which Cannon gave to the American Astronomical Society (AAS) to establish a regular prize for outstanding research by women astronomers. (The Cannon Award has been presented roughly every three years since 1934; since 1974 the Award has been made by the American Association of University Women with advice from the AAS.) Cannon regularly attended meetings of the AAS, serving as the Society's Treasurer for several years in the 1910s and as Councilor in the late 1930s.

Despite the value of her spectral classifications and the notice her work garnered elsewhere, Cannon received no official recognition from Harvard for decades. As early as 1911 a visiting committee report concluded that "It is an anomaly that, though she is recognized the world over as the greatest living expert in this line of work . . . she holds no official position in the university". It was 1938, three years before her death, before the Harvard University Corporation appointed Cannon, who was then 75 years old, a professor of astronomy.

Maury and Leavitt

Cannon classified; her system was easy to use, her personality was charming, her work was performed at an incredible rate. Only the first of these is applicable to another of the members of "Pickering's Harem", Antonia C. Maury, a dour and talented astronomer whose physical insights and boredom with drudgery did not well fit her for the routine work of spectral classification. Maury was born in 1866, the niece of Henry Draper. After her graduation from Vassar in 1887, her father implored Pickering to give Maury a job. She worked, off-again and on-again, at HCO until 1935.

Where Cannon's early tasks had included classification of a sequence of southern stars, Maury was assigned plates of the northern sky. She, too, was dissatisfied with Fleming's scheme (some of which was simply in error due to the poor quality of the early photographs) and devised her own. In addition to the relative strengths of various lines, Maury's system took note of the sharpness of the lines. Since an entire photograph could be blurry owing to a poor-quality observation, this usually meant that a classifica-

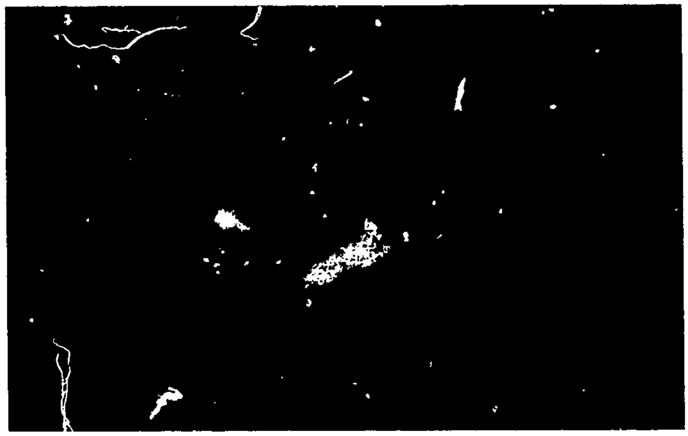
Antonia C. Maury (1866-1952) developed her own system for classifying the spectra of stars while at the Harvard College Observatory. Maury eventually left Harvard because she was unable to get along with Pickering. (Courtesy Harvard College Observatory).

4. It is a reflection of the mostly male make-up of astronomy faculties that the mnemonic with which most students remembered these spectral types for decades was "Oh, Be A Fine Girl, Kiss Me." Today students can substitute "Guy" for "Girl," or, better yet, as urged by Owen Gingerich at Harvard, come up with new mnemonics such as "Oh Boy, An F Grade Kills Me!" or "Oh Brother, Astronomers Frequently Give Killer Midterms!" — *Ed.*

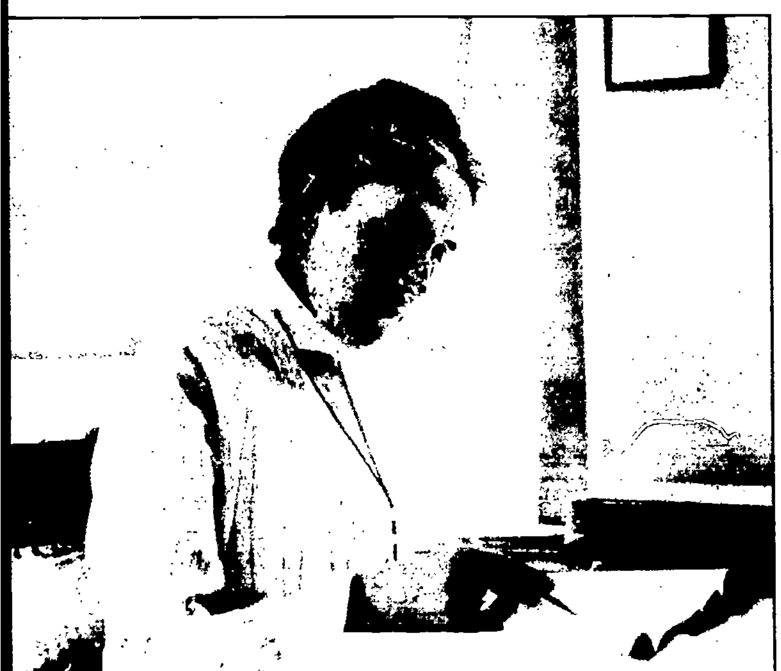
tion required the additional time spent examining a comparison plate. Pickering, who was proud of the efficiency of his computers, found this exasperating. Maury's classification of 681 stars was not ready for publication until 1897. Her classification scheme, with its 22 Roman-numeral types subscripted with three sharpness classes, was awkward to use. Her realization that there existed multiple classes of stars with the same spectral type contributed, though, to Ejnar Hertzsprung's recognition of the existence of the giant stars. He tried, in vain, to convince Pickering of the importance of Maury's sharpness criterion. In 1943 the AAS awarded Maury the Cannon prize for her work.

In addition to classification, Maury studied spectroscopic binaries — stars whose double nature is evident only through spectroscopic analysis. The first such double-lined star was discovered by Pickering and interpreted correctly, with Maury's help, as being due to two very close stars whose spectral lines shift as they orbit each other. Maury discovered the second-known spectroscopic binary, β Aurigae, and spent considerable time studying an extremely close pair, β Lyrae. As Cecilia Payne-Gaposchkin noted, Maury had a flair for identifying tough problems!

Perhaps the most brilliant of the early women astronomers at HCO was Henrietta Swan Leavitt, who came to the observatory as a volunteer in 1895. Leavitt, daughter of a Congregational minister, graduated from Radcliffe (or The Society for the Collegiate Instruction of Women, as it was known then) in 1892. Her work was interrupted for several years by an illness that left her hearing impaired. She returned to HCO on a permanent basis in 1902 at the age of 34.



At a distance of about 160,000 light years, the Large Magellanic Cloud (LMC) is the nearest companion to our Milky Way Galaxy. Henrietta Leavitt's study of variable stars in the LMC confirmed her discovery of the Period-Luminosity relation for Cepheids. (Courtesy A.S.P. Archives)

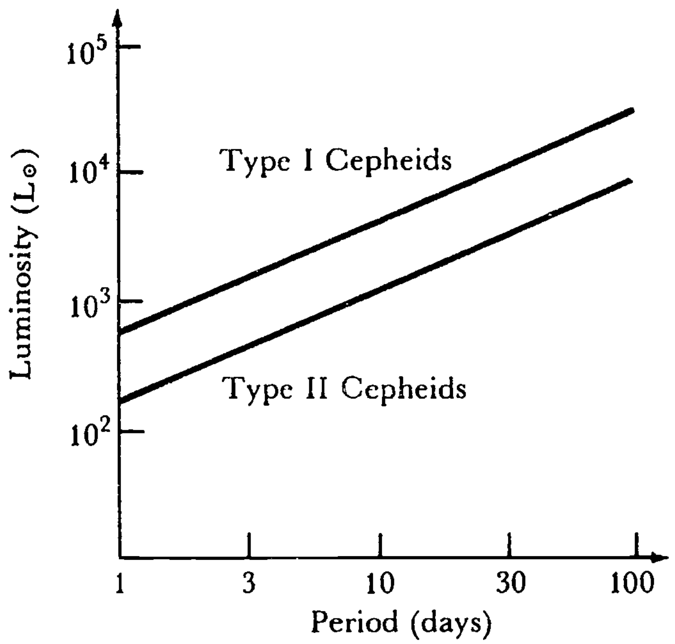


Henrietta Swan Leavitt (1868-1921) discovered the relationship between the period of brightness variations in Cepheid variable stars and their intrinsic average brightness. (Courtesy Shapley Collection, Niels Bohr Library, American Institute of Physics)

At HCO, Leavitt worked on a north polar sequence of stars to be used as standards for photographic photometry (the precise measurement of stellar brightnesses); her results were used until the advent of photoelectric photometry in the 1940s. She also worked cataloging variable stars, identifying over 2000 to add to Harvard's collection. As with most things the computers did, this was a tedious process, involving overlaying two photographs taken at different times, one negative and one positive, and looking for stars whose images were different sizes on the two plates.

It was in studying variables in the Magellanic Clouds that Leavitt made her greatest discovery. The Magellanic Clouds are small companion galaxies to the Milky Way, visible from the southern hemisphere; since they are at a great distance from us, about 160,000 light years, all the stars in, say, the Small Magellanic Cloud (SMC) are at roughly equal distances from us. (The example is often used that to a person in New York, all people in Los Angeles are roughly the same distance away.) Since the stars are all at the same distance, differences in observed stellar brightness must reflect intrinsic stellar differences. Leavitt found 25 of the variables called *Cepheids* (named for the prototype star of this type, δ Cephei) in the SMC, with periods between about 2 and 40 days, and discovered that the brighter the star, the longer its period of variability. Once the distance to the nearest Cepheids was found, this Period-Luminosity Relation, as it became known, meant that the intrinsic brightness of any Cepheid could be found from simple observations. From this relation and its apparent brightness, astronomers could then immediately "read off" the distance to the star —something that was quite difficult to find for any but the nearest stars.

The discovery of the Period-Luminosity Relation ultimately gave us our first means of measuring extragalactic distances and was used to demonstrate conclusively that many of the "nebulae" then known were actually galaxies in their own right. Leavitt,



The period of variability of a Cepheid variable star is directly related to its average intrinsic brightness or luminosity. Today, we know that there are actually two distinct types of Cepheids: Cepheids rich in heavier elements like calcium and magnesium (Type I) are inherently brighter than Cepheids poor in heavier elements (Type II). (From William J. Kaufmann's text Universe, *3rd Edition. © 1991 W. H. Freeman and Company, used with permission)*

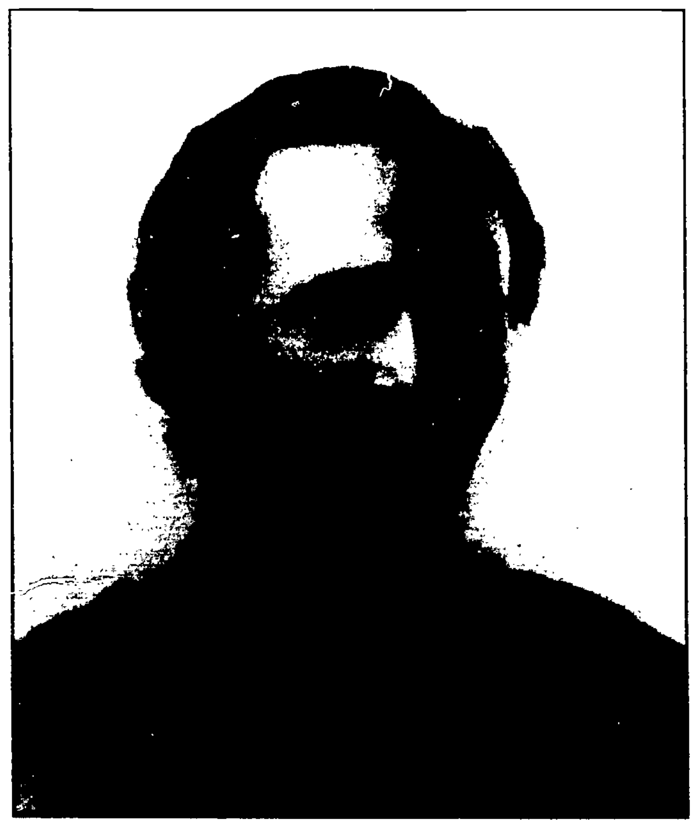
however, was not being paid to investigate the physical nature of variable stars nor to theorize about distances. The applications of her work were left to her male colleagues, while she returned to the drudgery of measuring plates. Unlike Maury, she does not seem to have complained about the work assigned to her. Still, it must have been frustrating, as Payne-Gaposchkin notes: "It may have been a wise decision to assign the problems of photographic photometry to Miss Leavitt, the ablest of the many women who have played their part in the work of Harvard College Observatory. But it was also a harsh decision, which condemned a brilliant scientist to uncongenial work, and probably set back the study of variable stars for several decades." Leavitt's work did receive some attention: Professor Mittag-Leffler of the Swedish Academy of Sciences deemed her contributions to be of such value as to warrant nomination in 1925 for the Nobel Prize. Leavitt had unfortunately died four years previously, although only 51.

Cecilia Payne-Gaposchkin

When Cecilia Payne came to HCO in 1923, she inherited Henrietta Leavitt's desk. Over the next fifty years, Payne played a significant role not only in the burgeoning field of astrophysics but also in widening the opportunities available to women in astronomy.

Payne was born in England in 1900. She attended Newnham College, Cambridge, where she became interested in astronomy after hearing lectures by Sir Arthur Eddington. She graduated in 1923 and came to the U.S., seeking better prospects for advanced study and employment than were available to women in England. The new director of HCO, Harlow Shapley, was establishing a graduate program in astronomy and had no difficulty with women students. Payne was offered one of the Pickering Fellowships (established for women students). In 1925 her Ph.D. dissertation, entitled "Stellar Atmospheres", was published by the observatory. Her degree (awarded by Radcliffe rather than Harvard due to her sex) was the first astronomy doctorate earned at Harvard; it has been called, by the notable astronomer Otto Struve (as late as 1960!), "undoubtedly the most brilliant Ph.D. thesis ever written in astronomy".

For her dissertation, Payne took stellar spectra from the Harvard photographic collection and combined measurements of spectral lines with theoretical predictions of how temperature and ionization state in a star's atmosphere should affect the strength of the line (predictions published in 1920-1921 by Meghnad Saha) to obtain a temperature scale for Cannon's spectral types. Payne also determined that stars, contrary to current belief, were mostly composed of hydrogen and helium. In discussions with Henry Norris Russell, at Princeton, Payne became convinced that this was impossible and did not publish her conclusion; sadly, she received no credit for this discovery several years later when Russell reached, and published, the same conclusion.

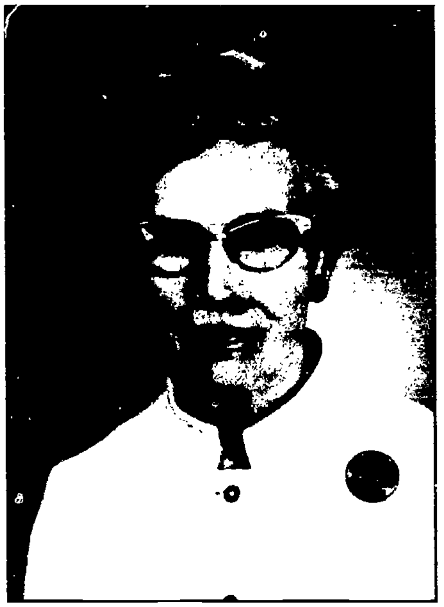


Cecilia Payne-Gaposhkin (1900 - 1979). (Courtesy A.S.P. Archives)

Following her degree, Payne worked for HCO: this meant constraints since the subjects of her research were expected to correspond to the goals of the observatory, which did not have the advanced spectroscopic equipment Payne would have needed to pursue her dissertation work. The bulk of her scientific life was spent on the study of stellar magnitudes and distances, and, following her marriage in 1934 to Russian emigré astronomer Sergei Gaposchkin, on variable stars. Together, she and Sergei determined light curves for about 2000 variable stars down to 10th magnitude.

Payne-Gaposchkin was one of the first women to try to blend research and family. "While marriage was deemed an asset in male candidates for teaching and observatory positions, it was a detriment for women. Female computers and professors were expected to resign their posts if they married, the better to assist their husbands".[5] Payne-Gaposchkin kept her position. (Payne-Gaposchkin further offended tradition by delivering a paper when five months pregnant with her first child; such behavior in the

5. Peggy Kidwell, in *Uneasy Careers and Intimate Lives: Women in Science 1789 - 1979*, Ed. Phina G. Abrir-Am and Dorinda Outram. Rutgers U. Press. — *Ed.*



Charlotte Moore Sitterly, winner of the A.S.P.'s Bruce Medal in 1990, the year of her death, is best known for her work on atomic energy levels (see Mercury, *Nov/Dec 1990, p. 179). (Courtesy National Institutes for Standards and Technology)*

E. Margaret Burbidge has played a major role in research that showed that heavy elements are constantly built up from lighter ones within stars. She also has done important work on the rotation of galaxies, which led to some of the first estimates of the masses of galaxies, and on quasars. From 1972 to 1973 she served as head of the Royal Greenwich Observatory, the first woman director in its 300-year history. She is currently a professor at the University of California at San Diego. (Courtesy University of California at San Diego)

Sidney Wolff is currently Director of the National Optical Astronomy Observatories, which includes Kitt Peak National Observatory (in the background). Wolff is well known for her research on stellar spectroscopy and stellar atmospheres, with an emphasis on A-type stars. (Courtesy National Optical Astronomy Observatories) future was vehemently vetoed by her boss, Harlow Shapley!)

Payne-Gaposchkin was by and large, as with the women before her, recognized but not adequately rewarded for her work. She was elected to the RAS before she graduated from Cambridge, won the (first) Cannon prize in 1934, was elected to the American Philosophical Society in 1936 and the American Academy of Arts and Sciences in 1943, and was awarded the AAS Henry Norris Russell prize for a lifetime of eminent astronomical research (although this recognition came only in 1976). Despite being one of the most accomplished astronomers of her time, Payne-Gaposchkin was never elected to the National Academy of Sciences (NAS), did not receive the A.S.P.'s Bruce Medal, was turned down for numerous possible appointments, and did not receive any official recognition from Harvard for decades. As she noted in 1930: "... I received absolutely no recognition, either official or private, from Harvard University or Radcliffe College: I cannot appear in the catalogues; I do give lectures, but they are not announced in the catalogue, and I am paid for (I believe) as 'equipment'; certainly I have no official position such as instructor." In 1956, at the age of 56, Payne-Gaposchkin was appointed full professor and made chair of Harvard's astronomy department, the first woman to hold such a position not specifically designated for a woman. The appointment prompted the rather large Payne-Gaposchkin to note that she found herself in "the unlikely position of a thin wedge".

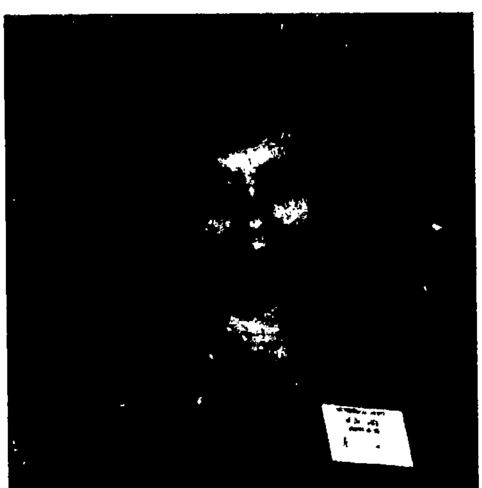
Conclusion

The "wedges" have had some effect, albeit slowly. The American Astronomical Society (AAS) saw its first woman Vice President, Charlotte Moore Sitterly in 1958. E. Margaret Burbidge (who has participated in fundamental work on stellar nucleosynthesis, galaxy dynamics, and quasars) served as AAS President from 1976-78, and became the first woman to receive the Bruce Medal in 1982. Sidney C. Wolff (stellar activity and composition), currently head of the National Optical Astronomical Observatories, has recently been elected and will take office as the AAS's second woman president in 1992; she served as A.S.P. President in 1985 and 1986. Graduate programs do not, at least overtly, discriminate against women (although Princeton University, a bit of a holdout, did not admit women to its graduate astronomy program until 1975). Colleges are less likely to deny women faculty timely promotion and tenure than in Payne-Gaposchkin's day. Observatories no longer object to women observers, although some did well into the 1960s (the living quarters on Mt. Wilson were dubbed "The Monastery"; since there were no women's restrooms, women obviously could not be allowed to come to the mountain to observe!). Several women astronomers have been elected to the National Academy of Sciences (NAS), including Burbidge in 1978 and Vera Rubin (at the forefront of the quest for "dark matter") in 1981. The list of prominent women astronomers is certainly longer than it was in 1950, when among a total community of about 300 there were about 50 women astronomers with Ph.D.s from U.S. institutions.

Authors Andrea Dobson (left) and Katherine Bracher (right) with Whitman College's 1876 Alvan Clark refracting telescope. Bracher's research interests range from the history of the A.S.P. to records of ancient eclipses found in Greek sources and archaeoastronomy. Dobson studies magnetic activity in stars similar to the Sun.

Still ... The 11 female charter members of the AAS constituted about 10 percent of the society; that percentage, having risen somewhat and fallen somewhat over the years, stands now at about 11 percent, although the total number of women members is, of course, larger. Similarly ercentage of astronomy doctorates awarded to women each ye. the U.S. peaked at about 25 percent in the 1920s (and was about as high during WWII) and then fell to about 10 percent in the late 40s. Women professors still are paid, on average, about 93 percent of what their male peers receive. The 1976 Smithsonian exhibit on American astronomy not only didn't include Maria Mitchell, it didn't include any women.

Women's attitudes toward themselves have certainly changed over the past two centuries. Caroline Herschel wrote that "I did nothing for my brother but what a well-trained puppy dog would have done: that is to say, I did what he commanded me. I was a mere tool which he had the trouble of sharpening". Maria Mitchell, in defense of women in astronomy, wrote that "[o]bservations of this kind are peculiarly adapted to women ... The eye that directs a needle in the delicate meshes of embroidery will equally well bisect a star with the spider web of the micrometer." Cecilia Payne-Gaposchkin, more on "offense", frequently advised young women contemplating a career in astronomy, "Do not undertake a scientific career in quest of fame or money ... Undertake it only if nothing else will satisfy you, for nothing else is probably what you will receive". A significant number of young women seem to be taking that challenge: more than 20 percent of the AAS members under 30 are female. ■



Katherine Kron served as editor of the Publications of the A.S.P. *from 1961 to 1967, the first woman to hold the editorship of a major astronomical journal. (Photo by A. Fraknoi)*

Some Glimpses from My Career

Dorrit Hoffleit
Yale University

Dorrit Hoffleit, Director of the Maria Mitchell Observatory, in 1975. (Photo by Rick Steadry, courtesy Dorrit Hoffleit)

Soon after graduating from Radcliffe College, I got two job offers. One was at Harvard College Observatory (HCO) to search on existing Harvard photographs for variable stars and analyze their light curves. The remuneration was to be 40 cents an hour, amounting to about $70 a month, at a time when my rent was $40 a month. The other was an assistantship to a statistician at another college, paying about $150 a month. Doing astronomy was well worth the difference! Within a year of my appointment at HCO there came the Great Depression of October 1929. Since the Observatory's Director Harlow Shapley was able to hire two women for the price of one man, we women kept our jobs, while some men were left stranded. It is not often in professional life that it has been a blessing to be an under-paid woman.

Besides working full time I carried on graduate studies at the slow rate of a course a year until I acquired an M.A. That was the highest degree for which I felt qualified. After that I spent evenings happily in the Harvard Observatory plate stacks doing what I pleased, other than my day-time job. Thus I made a pioneering study of the light curves of the meteor trails that had been acquired by pure chance on Harvard photographic plates. I wrote a paper on this which Shapley asked meteor expert Ernst Öpik to referee. His response being favorable, Shapley submitted the paper to the *Proceedings of the National Academy of Sciences* where it was published. This is probably what inspired Shapley to encourage me to continue graduate studies. When I indicated some misgivings about passing examinations, Bart J. Bok admonished me, "Dorrit! When 'God' recommends that you do something, it is your *duty* to do it!" This became the happiest era of my life.

At Harvard, Shapley frequently suggested projects; but I rarely felt that he ordered compliance except on rare occasions when he was in a hurry for results to be presented at upcoming meetings. Thus I felt complete independence (not duplicated in my later employment at Yale). If Shapley could have remained director forever, I should not have left Harvard; for I would probably have carried out independent research of perhaps mediocre caliber, making use of the famous plate collection from which so much remained to be discovered and explored. Nowhere in the world was there a collection of half a million plates covering the sky from pole to pole starting for many purposes as early as 1882. I worked on meteors, variable stars, and spectral classification — especially for the determination of absolute magnitudes (the intrinsic, as contrasted with the apparent, luminosities of the stars).

Shortly before he reached mandatory retirement age, Shapley asked me to sample plates in the various series, selecting a pile of those I felt could safely be discarded, another of ones I thought might be controversial, and some of the poorer plates I thought should nevertheless be kept. When I finished, he would check my selections and draw his own conclusion, namely that the number of plates sufficiently poor to justify discarding was so small it would be a waste of time to search for them. Throw them away if you happen to come across any, he told me, and then be sure to make an appropriate note in the record books and card catalogs so that no one would subsequently search for them in vain.

But the new Director had other plans. His own work made comparatively little use of the plate collection, whereas office space seemed to be at a premium. He ordered his executive secretary, who had little if any experience in astronomy, to throw away the poorer plates to the extent of removing about a third of the collection, clearing the equivalent of one of the three floors of the plate vault. Moreover, this was being done in such a hurry that no records were kept of what was discarded. This wholesale destruction was driving me crazy. Finally I wrote the Dean what I thought. After that life naturally became intolerable and although I had tenure at Harvard, I resigned (nor was I the only one to do so).

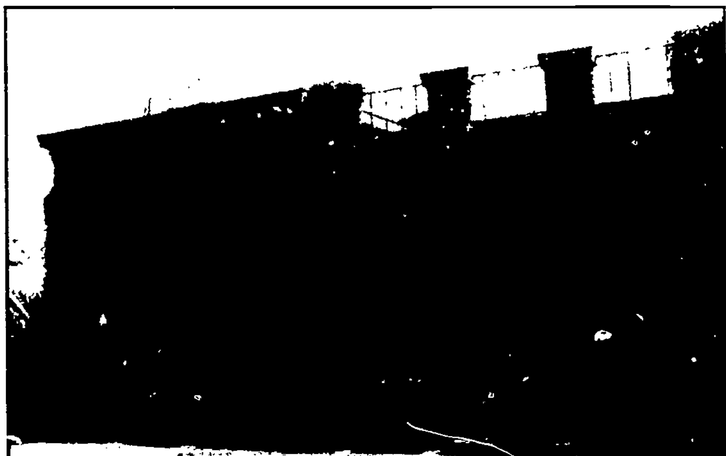
At this time the Director of the Maria Mitchell Observatory in Nantucket was about to retire and I was offered her position. However, the Maria Mitchell Association, of which the Observatory was a part, was in financial straits and could afford only a half-time Director and no assistants. Dr. Dirk Brouwer, Director of the Yale Observatory, was the Chairman of the search committee to select the new Observatory Director. He offered me a half-yearly appointment at Yale to take charge of the zone catalog work from which Miss Ida Barney was also about to retire after having completed as author or co-author some 20 volumes of stellar proper motions, mainly under the direction of the pioneer, Frank Schlesinger. This work, dealing with the proper motions of the stars (the rate of change in their positions on the sky), appealed to me because proper motions were important (among other things) for the calibration of the spectroscopic absolute magnitude criteria on which I had been working at Harvard. There were never enough data for accurate calibrations!

On Nantucket the equipment had been designed and erected in 1912 especially for photographic investigations of variable stars. By the mid-1950s this equipment seemed somewhat outdated, modern devices being either faster or yielding higher accuracy. However, slowness has advantages for training purposes, and continuity of plate series is important in the study of variable stars. What better use for this equipment than the establishment of a summer research participation program on variable stars for women undergraduates? After all, the Observatory was a memorial to America's first woman astronomer. As an early advocate of women's rights she had remarked, "I believe in women more than I do in astronomy."

For student housing at the Maria Mitchell Observatory we had available only one dormitory room, so that we could not very well be co-educational. Students — then as now — needed summer jobs, and I applied annually for funds wherever I could, first from the Office of Naval Research, then mainly from the National Science Foundation. Gradually we were able to expand, and in my last few years more living space became available so that we were able to employ boys as well as girls. This became important for retaining government support, which now requires nondiscrimination against men. In all, over a span of 22 years I had 100 girls in my summer program. Over 25 of them now have Ph.D. degrees and they have far surpassed my own abilities and achievements. Seeing what they have accomplished is one of the greatest joys of my old age. And to think that if it were not for my traumatic departure from Harvard, I should not have experienced the pleasures of associating with these bright young people.

At Yale, unlike HCO, I found little opportunity for independent research. Here it seemed women were expected to do only what they were told. Once Dr. Brouwer asked me to do something, but when I told him I had already done it on my own, I was reprimanded for "such independence!" Miss Barney, whose final catalog I had helped her to complete, had asked me to write the introduction. When I included a paragraph on the statistics of the double stars it contained she crossed it out, saying, "Dr. Schlesinger did not include that, so why should you?"

In addition to the zone catalog work, I was asked to up-date the *Yale Catalog of Bright Stars*. The first edition had been published in 1930; the second in 1940. With part-time assistants I prepared the third edition which came out in 1964, and with Carlos Jaschek the fourth in 1982, each of the last two containing a larger number of categories of data than its predecessor. A fifth version is now available on tape from Wayne Warren at Goddard. The time is not yet ripe for this to be made into a printed version. Warren and I have made numerous corrections to the fourth edition and added new data as they have happened to come to our attention. However, we have not had time to make a systematic search of the literature and therefore have undoubtedly overlooked much relevant new material. If we were to publish at this stage we would surely be swamped with criticism. However, as the additions and revisions we have already made amount to several thousand, we are happy to share the partially updated entries with those who need them.



Dorrit Hoffleit at the entrance to the Maria Mitchell Observatory. (Courtesy Dorrit Hoffleit)

The birthplace of Maria Mitchell (right) and the Vestal Street site of the Maria Mitchell Observatory on Nantucket. (Photo by W. Frederick Lucas, courtesy Maria Mitchell Association)

Henrietta Hill Swope: Variable Stars in the Milky Way and Andromeda

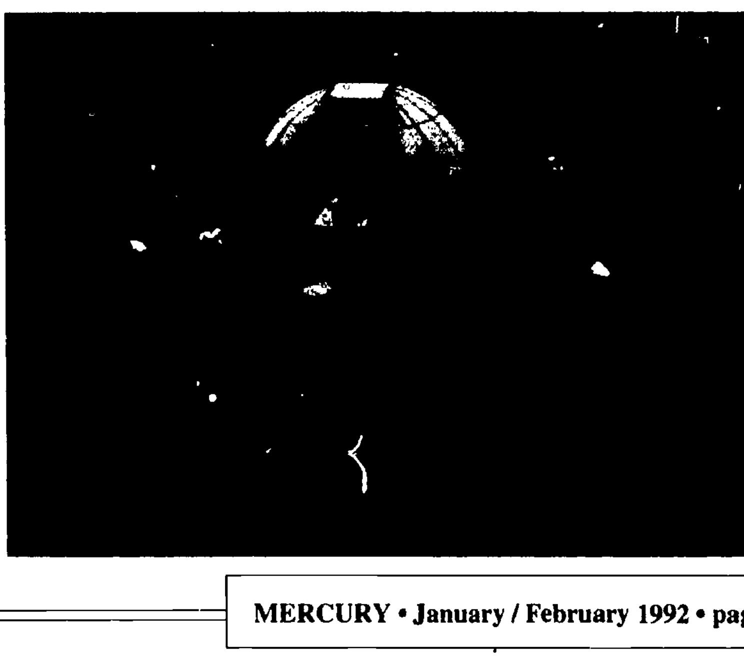
In the early 1950s Henrietta Swope studied the variable stars on Palomar photographic plates to establish a new distance to the Andromeda "Nebula" of 2.2 million light years. The irony of the story is that she almost pursued a career in business. Her course in astronomy at Barnard College did not inspire her to continue in science. So in 1925 she entered the graduate School of Commerce and Administration at the University of Chicago. In a letter to her brother she confided, "I feel quite out of place and behave like a wee mouse among many fierce cats."


Photo courtesy Mt. Wilson Obs.

At that time she also corresponded with Margaret Harwood, the Director of the Maria Mitchell Observatory. As a friend of the family, Harwood knew of Swope's childhood love of the stars. So she persuaded Swope to take advantage of the opportunities for women at Harvard College Observatory. It was fortuitous. In the words of Cecilia Payne-Gaposchkin: "Henrietta Swope...evinced an extraordinary flair for discovering variable stars...in [her] capable hands...the Harvard programs on variable stars in the Milky Way were bearing fruit in enormous quantities." The results that Swope published in the Harvard *Annals* caught the eye of Walter Baade at Palomar when he began to photograph the variables in the Andromeda Nebula. He needed a collaborator to study all the plates and Henrietta Swope was a prime candidate. Her work put a more precise value on the distance to our neighboring galaxy than Baade's rough estimate. For her results the AAS awarded her the Annie Jump Cannon Prize in 1968; Basel University conferred on her a Doctorate *honoris causa* in 1975; and her alma mater, Barnard College, awarded her its Distinguished Alumna Award in 1975 and its Medal of Distinction in 1980.

Barbara L. Welther
Smithsonian Astrophysical Observatory

One chore that I did not enjoy was supervising a tremendous amount of key-punching and verifying of some 75 miscellaneous astrometric and other catalogs only a few of which had relevance to either the southern zone catalogs then in progress or to the *Bright Star Catalog*. In 1961 Brouwer had signed a contract with the U. S. Naval Observatory for putting numerous catalogs on punch cards, one institution doing the punching, the other the verifying, and I was to supervise the Yale half of this massive undertaking, involving well over a million cards. (The project was described in the *Astronomical Journal*, volume 72, page 586, in 1967.) For someone on half time only, with a figurative whip almost constantly held over her to produce catalogs faster and faster, this was an unwelcome burden. Amazingly, when at last the assigned catalogs were completed, considerable funds still remained on the contract. After Brouwer and I seemed to have exhausted all the materials for which he conceived a potential use, I suggested the *Henry Draper Catalog* (the *HD*), a ten volume catalog of the spectral classes of some quarter million stars. At first, Brouwer objected as he had no need for the *HD* in his own celestial mechanics applications. I, on the other hand, found frequent use for it; so finally he reluctantly agreed rather than forfeit the remaining contract funds. This turned out to be immensely fortunate, as the tapes made from the IBM cards certainly expedited Nancy Houk's identification of the *HD* stars when at the University of Michigan she undertook her important reclassification of those stars on the more modern MK system. The *HD* classes were correlated only with stellar temperature (the familiar OBAFGKMS series); the MK with *both* temperature and intrinsic luminosity. (Nancy Houk, incidentally, had been one of my student research participants on Nantucket in 1962.)


A summer intern uses the telescope at the Maria Mitchell Observatory, Nantucket. (Photo by W. Frederick Lucas, Maria Mitchell Association)

* * *

Among the joys of retirement has been the fact that I have been permitted to keep my office at Yale and am privileged to say *yes* or *no* to any of the numerous requests for miscellaneous information that come my way. As it gives one a good feeling to be considered knowledgeable on usually obscure facts, I have hardly ever learned to say *no*, and spend many hours, even weeks and occasionally months, delving into historic or observational records in order to answer the requests. Now, for the past decade or more at Yale, I have become as happy and independent as I had been in my youth at Harvard. ■

One Woman's Journey

Ann Merchant Boesgaard

University of Hawaii

Ann Merchant Boesgaard, having just received her Ph.D., in front of the 120-inch telescope dome at Lick Observatory (above) and (below) during graduate school in 1963. (Courtesy Ann Boesgaard)

Editor's note: Ann Boesgaard was the first woman to be elected President of the Astronomical Society of the Pacific, in 1976. An astronomer at the University of Hawaii, she is also the winner of the 1990 Muhlmann Prize for her research on light elements and the evolution of stars. As we prepared this special issue on "Women in Astronomy," we asked Dr. Boesgaard to reminisce about her life and career in astronomy and she very kindly wrote the following article for *Mercury* readers.

Science was my favorite subject (after gym class) when I was in grade school. I focused on this quite early, learning the multiplication tables in kindergarten, and the planets and some constellations in second grade. The weekly science program on FM radio, with all its extracurricular activities, was the highlight of fifth, sixth, and seventh grades for me. In high school I found math to be the most fun and by my senior year in physics class I realized that I could fold my enjoyment of astronomy, physics, and math into one by pursuing a career in astronomy.

College Years

My high school physics teacher maintained that at co-ed colleges the male science students would get all the special attention and special opportunities that arose. In the late '50s men were typically the sole breadwinners in the household; the social attitude that prevailed was that training them was higher priority than training women. Since I knew I was going to have a career and wanted to be well-trained, I happily went to Mount Holyoke College (all women) which had an excellent reputation in science. My determination to pursue a career may have been subtly influenced by my home life: my older sister and I lived with our divorced mother, our widowed grandmother, and our single great aunt — all women role models who were independent (although not necessarily by choice).

The Holyoke years increased my interest in astronomy, physics, and math and I basically took a triple major in these subjects. We had distribution requirements to fill and I had wonderful times in classes like music, psychology, philosophy, and English composition. But there were the inevitable difficult social situations. One I recall was square dancing at a social mixer when my partner for the set asked me what my major was; upon learning that it was astrophysics, he walked off the dance floor, leaving seven of us to improvise.

In that era we had weekday curfews at 11:00 p.m. and could not go out before 6 a.m. This interfered with some astronomical events, of course. Such a fuss to get special permission from the Dean to observe a lunar eclipse in the wee hours! And I have to admit to sneaking out of the dorm at 5 a.m. in dark clothes to use the telescope for some other event; fortunately the campus security did not notice, or chose to ignore, the open dome at the observatory. One fall I was putting together a transistor radio, using a soldering iron in my dorm room. My roommate's academic advisor was in complete distress that I was operating a "blow-torch" in our room. But aside from a few strange incidents like these, education there was a wonderful adventure.

Graduate Training

Then came the question of where to go to graduate school. My dream was to go to California where the big telescopes were. Caltech was not a place for women — only one had been admitted in astronomy by then, in 1958. But the University of California at Berkeley had a good history of women graduate students in astronomy (although not on the faculty then) and that was where I chose to go. There were typically three to five women astronomy students enrolled at Berkeley at any given time. (Thus, my classes went from 100% women in my first two years of college, to 50% women in astronomy classes in the last two years, then to 10% women in graduate school.) We had a good camaraderie as graduate students; I recall no overt gender bias and we had no special women's activities or support.

My undergraduate advisors predicted I would not get to use the big California telescopes even if I were brave enough to go so far away. Not true. As a second year graduate student I was an observing assistant for George Wallerstein (now at the University of Washington) on the 120-inch telescope at Lick Observatory. I kept leaving the coudé room[1] down below to go to the observing floor to admire the big silent machine. I did my Ph.D. thesis observations with George Herbig on the 120-inch, spending close to 30 nights there. Problems in understanding the abundances of the elements lithium and beryllium in the stars and what we can learn from them were the subjects of most of those observations, and these problems still occupy me today.

Lithium and Beryllium Studies

The light elements, lithium and beryllium, provide clues to a number of astronomical problems. Unlike the other chemical elements, they are easily destroyed by nuclear fusion reactions inside of stars. Any place in a star where the temperature is above about two million degrees, lithium and a proton will fuse to create two helium atoms. For the Sun, that temperature boundary includes the inner 97.5% of the solar mass!

Now, when we look at spectra of stars, we observe only the very outer layers, and in these cooler regions you might expect that lithium and beryllium have been untouched. But this is only true if the outer material doesn't ever mix with the material further down. In fact, stars often find ways to mix different layers; primary among them is the process of *convection*, through which hotter material tends to rise and cooler material will sink. In the outer layers of stars like the Sun (a category called low-mass dwarf stars), mixing transports lithium and beryllium to lower (hotter) regions where it can be destroyed. So the amounts of lithium and beryllium that a star shows on its surface tells us how effective the mixing is and how deep into the star it penetrates. If it penetrates to regions of 2 million degrees it will destroy lithium, but it must go to over 3 million to destroy beryllium. Thus nature provides a way for us to probe the otherwise invisible interior of a star. The Sun itself is an interesting example of this process: it now has only 1% of its original lithium left, but all of its original beryllium, indicating that material has not reached the depth where the temperature is as much as 3 million degrees.

Because they are so easily destroyed, lithium and beryllium cannot have been made inside stars, where it is so hot; another origin for them must be "invented." One solution is what are called *spallation reactions*, which occur when energetic cosmic rays (high energy particles) bombard atoms of abundant elements like carbon, nitrogen, and oxygen. So instead of being built up by fusion like other elements, lithium and beryllium are made when the heavier C, N, and O atoms are broken into pieces. One interesting consequence of this is that we can gain information about the chemical evolution of our Galaxy by looking at the buildup of beryllium over time.

Another way lithium can be produced is under conditions that are far denser and hotter than the stars — conditions that prevailed during the first 15 minutes of the universe after the Big Bang. It is one of the elements synthesized in that earliest epoch of time. If we can find lithium now whose abundance has not been changed significantly by processing in stars (what we call *primordial* lithium), its relative abundance (compared to other primordial elements) can help us to understand some of the details of the earliest evolution of the universe.

When we look at later stages in the

A rear view of the Kapteyn Cottage on Mount Wilson (Boesgaard is in the foreground). Women who wanted to use the telescopes there were originally forced to stay in this small, unheated cottage with no hot water, while men stayed in a heated dormitory. This photo was taken in spring 1988. (Courtesy Ann Boesgaard)

evolution of stars — stages our Sun has not yet reached — we can also learn important details from studying lithium. As stars evolve into giants, their internal structure changes and, as a result, the surface lithium is redistributed through the star. So lithium again provides a probe for us of the internal restructuring that takes place. I did my Ph.D. thesis research on the amount of lithium in cool, evolved giant and supergiant stars (of the type astronomers denote by the letter M). It turned out that except for a handful of stars, they actually had significantly less lithium than they would have showed when they were dwarf stars. Mixing of the former stellar surface had gone very deep into the giant. The handful of stars rich in lithium may be yet another source of lithium for the universe, by the way.[2]

Becoming a Post-Doc

After finishing my Ph.D. in 1966, I was impressed to find myself listed in American Men of Science. (It was only renamed American Men and Women of Science in 1971.) During graduate school I was irrepressibly single, having the (wrong) notion that marriage meant darning socks (yuk!), cooking (gasp!), and washing dishes (ick!). But four days after my final Ph.D. oral exam, I married Hans Boesgaard, and started to try to catch up with his culinary wizardry. (Worn socks, it turned out, were tossed, not darned as in my grandmother's era.)

I had applied for a prestigious Carnegie Fellowship to go to the Mount Wilson and Palomar Observatories as a post-doc. Margaret Burbidge reports in *Science Magazine*, (volume 252, p. 1604, 1991) that when she applied in the late 1940s she got an angry letter back. "He thought I should have known that women aren't allowed." By 1966, when I applied, they were somewhat more "open," but upon learning that I was getting married, they thought that that meant I was no longer interested.

However, Jesse Greenstein did not have those reservations and hired me as a post-doc at Caltech. And from there I could have access to the Mount Wilson telescopes (I suppose to the consternation of some of the Carnegie folks). Like Margaret Burbidge, who eventually was able to observe at Mt. Wilson under her husband's allocation of time (which many astronomers found humorous because he is a theorist), I too stayed in an unheated cottage with no hot water. The men stayed in a heated "monastery" with warm showers. But unlike Margaret, I was allowed to take my meals in the monastery — times had changed. I did *not* find it a heady experience to be the first woman to follow the tradition of sitting at the head of the table because I was observing at the largest telescope, the 100-inch (with the 60-inch observer to my right and the solar observer to my left), and ring the dinner bell for the "maids" to bring the next course. And I was not the least thrilled to have to make a fire in the potbellied stove in the cottage after observing those long, cold winter nights. Washing my face in the cold water in the kitchen sink was not so great either, and who had time to make hot water in the kettle?

But I loved observing with that venerable telescope, so quiet and peaceful, with the strains of American Airlines "Music 'til Dawn" coming over the radio. And I was delighted to have the opportunity to collect so much data and to learn so much about stellar spectroscopy in those times. I measured the relative amounts of the three magnesium (Mg) isotopes in stars then from a study of the molecular MgH bands in K-type dwarfs and giants. My post-doc-

The University of Hawaii's 88-inch telescope under construction atop the cinder cones at the summit of the dormant volcano Mauna Kea. Lake Waiau is in the foreground. (Photo by Agatin T. Abbott, University of Hawaii)

2. For more on Dr. Boesgaard's research, see the article on her Muhlmann Prize in the Nov/Dec 1990 issue of *Mercury* (pp. 182-185). — *Ed.*

toral year was capped by a trip to the International Astronomical Union General Assembly in Prague in 1967 where I was invited to present a paper on beryllium in stars at a joint discussion.

Finding a Position

During that first year we had a commuter marriage, before the term was invented. My husband was at the University of Hawaii (UH) while I was at Caltech. That introduced us to huge telephone bills, lots of long airplane trips (in the days before frequent-flyer mileage programs), and the discontinuities of two apartments, two refrigerators, two closets — never quite remembering which clothing or food was where. Hans' business — making the UH 88-inch telescope for the 14,000-foot peak of an extinct volcano on the big island — brought him to Southern California often, and I learned to put my research in a briefcase and work at an office at UH that John Jefferies was kind enough to provide. So we managed to be together almost 75% of the time and I benefited from interacting with two sets of colleagues.

Then I was offered a position as an Assistant Professor at the University of Hawaii, which I accepted with alacrity. The 9-month salary for that position is emblazoned on my memory: $8868. It was an exciting and challenging time; we were building up a new graduate program and a new observatory in what we knew to be the best place on the planet for an observatory. Clearly, our early prejudice has been validated by the many telescopes from all over the world that now exist and are planned for Mauna Kea.

The 88-inch telescope was dedicated in 1969, but we had made some observations before that. I took the first spectrogram with the coudé spectrograph of Alpha Centauri, the nearest star to the Sun, which at a declination of 60 degrees is definitely a southern hemisphere object. Mauna Kea is at a latitude of +20 degrees and an altitude of 14,000 feet, and therefore has a huge reach across the sky and very deep into it. A short paper on the age of Alpha Centauri resulted from these first observations. There was some thought that because the star's companion Proxima Centauri was a flare star, that the whole system must be quite young. Since Alpha Centauri is the same temperature and luminosity as the Sun, one way to test this idea was to compare it to the Sun in a number of other properties that are thought to be related to a star's age. Wendy Hagen and I studied the amount of lithium, the rate of rotation, and the degree of activity caused by magnetic fields and determined that Alpha Centauri was at least as old as the Sun.[3]

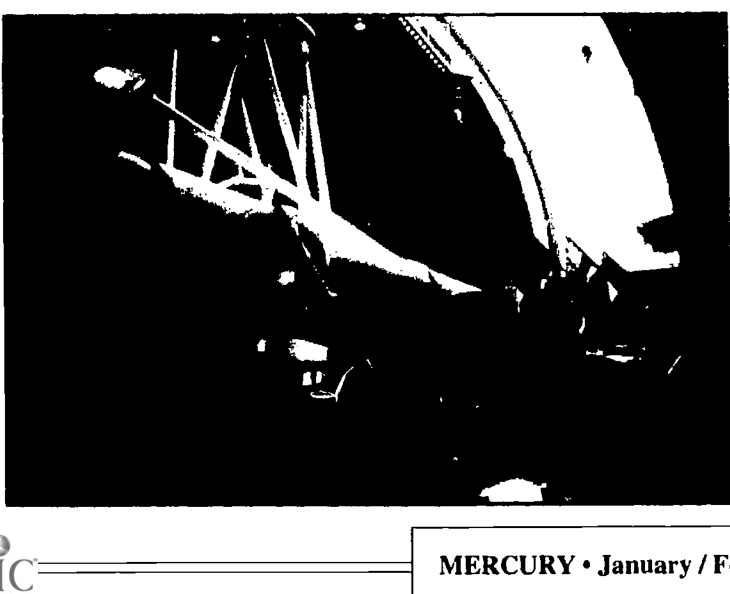
The Growth of Hawaiian Astronomy

As our graduate program in Hawaii was growing, so was the collecting area of the telescopes on Mauna Kea. The French were the first to recognize that we had developed a fantastic site for astronomical use. They were able to persuade the Canadians to join them in what became the 3.6-meter Canada-France-Hawaii telescope (CFHT). At a memorable dedication ceremony in 1979, the anthems of Canada, France, the U.S.A., and Hawaii reverberated through the dome. Although our first observations were with photographic plates, these were soon replaced by electronic detectors. Pioneering work on image quality at CFHT brought the median image size from 2 seconds of arc in 1980 to 1 second in 1984 to the present 0.75 seconds, with occasional nights of 0.3 to 0.5![4] It is this telescope that I have been privileged to use for most of my scientific work. Two infrared telescopes were also built on Mauna Kea, one a 3.0-meter by NASA, the other a 3.8-meter by the United Kingdom. These too were dedicated in 1979. They have been joined by two sub-millimeter wave telescopes: a 15-meter dish operated by the United Kingdom, the Netherlands, and Canada, and a 10-meter dish built by Caltech.

One entertaining project was a study of the star astronomers call Alpha Orionis, known by most people as Betelgeuse, one of the brightest and reddest stars in the sky. I chose to observe it at ultraviolet wavelengths where it is quite faint; I wanted to study the emission lines of ionized iron to learn about the outermost regions of this distended supergiant. Taking long exposures on this very bright star seemed a bizarre thing to do, but not as bizarre as the motions that were revealed by the structure of those emission lines. There was evidence for infalling material as well as an expanding envelope around the famous red giant! I spent part of a sabbatical leave in Paris puzzling out this structure with the help of Christian Magnan. And later while my husband was in Italy working on the NASA Infrared Telescope, I spent time at the Nice Observatory still puzzling over this strange mix. The two months there were enhanced by *rendezvous* every weekend with my husband in romantic places like Florence, Cannes, Rome, and Venice.

continued on page 37

3. For more on the Alpha Centauri system, see the article by D. Soderblom in the Sep/Oct 1987 issue of *Mercury*. – *Ed.*

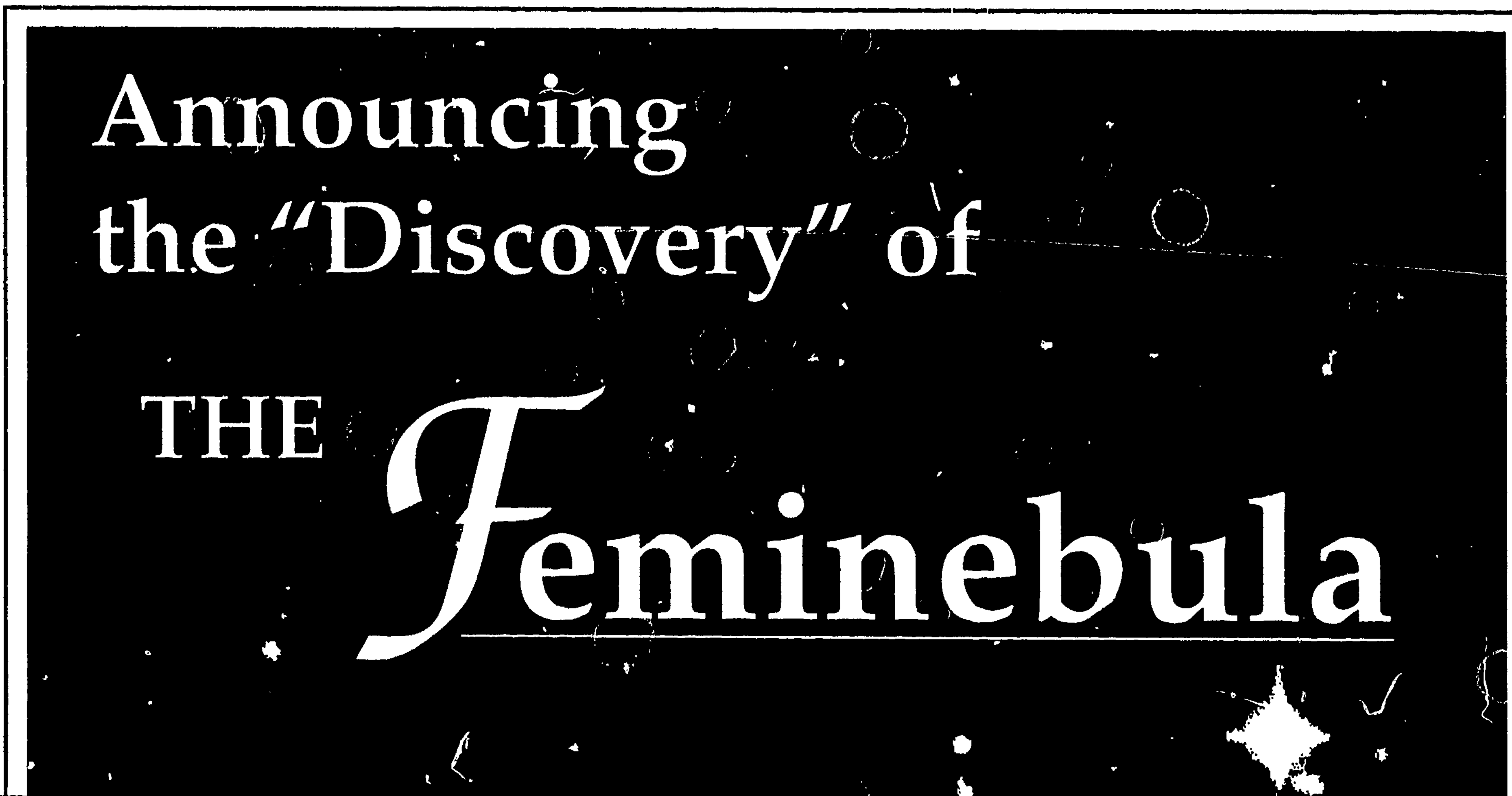


The dedication of the Canada-France-Hawaii Telescope on September 28, 1979. Also atop Mauna Kea, the telescope has a mirror 3.6 meters across. (Photo by Dale P. Cruikshank)

4. A second of arc is one-sixtieth of one-sixtieth of a degree on the sky. Put in practical terms, it is the size that a U.S. dime would appear when seen from two miles away! — *Ed.*

Mercury "Photo" Feature

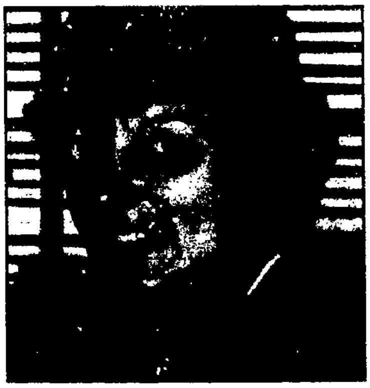
A whimsical creation from the special
"Women in Astronomy"
issue of ***Mercury,*** the Journal of the
Astronomical Society of the Pacific.



Concept and Design by Janet Doughty

Shortchanging Girls

Nadine Barlow
NASA Johnson Space Center



Nadine Barlow studies the geology of Mars at NASA's Lyndon B. Johnson Space Center in Houston, TX. Her current research looks at Martian impact craters to determine weathering at possible landing sites. She is also president of the Clear Lake, TX, branch of the American Association of University Women and recently chaired the steering committee for the Texas State AAUW Educational Equity Roundtable.

A major movement is afoot in the United States to improve the educational environment for today's students and better prepare them for tomorrow's challenges. However, recent studies indicate that the methods that encourage Caucasian boys in fields such as science, math, or English, may not necessarily work for girls or ethnic minorities. A recent study by the American Association of University Women shows that a student's sense of self-esteem can dramatically affect how well that student likes certain subjects and thus affect his/her career aspirations.

The American Association of University Women (AAUW) was founded in 1881 to promote education and equity for women and girls. Today this national organization of over 135,000 members works to help women meet the demands of our increasingly complex society. Although traditionally AAUW has worked primarily to provide opportunities for women pursuing higher education, in recent years the organization has taken the lead in improving the educational environment for young girls. In the fall of 1990, AAUW commissioned Greenberg-Lake: The Analysis Group to survey 3000 girls and boys ages 9 to 15 across the United States on their attitudes about themselves and their aspirations. Three major conclusions arose from the study:

1) both boys and girls experience a decline in self-esteem as they get older but the decline is more pronounced for girls;
2) adults have the greatest impact on adolescents' self-esteem and aspirations; and
3) boys and girls who enjoy science and math tend to retain higher levels of self-esteem and are more likely to achieve their aspirations.

The decline in self-esteem was the most interesting finding of the survey. Girls at 9 years of age tend to be very confident, assertive, and self-assured, but by the time they reach 15 years of age they are much less confident about themselves and their abilities. Girls emerging from adolescence have a poor self-image, are very concerned about their appearance, and feel constrained in the future options permitted them by societal expectations. Boys also suffer a decline in self-esteem between the fourth and tenth grades, but the decline is not as dramatic as it is for girls: In

(From the A.S.P. Archives)

fourth grade, 67% of boys and 60% of girls said they were happy with the way they were, whereas by tenth grade 46% of the boys and only 29% of the girls agreed with that statement. The survey also showed that boys were more confident in their talents and abilities and were more willing to speak up in class than were the girls.

We often believe that teenagers are more easily influenced by the attitudes of peers than by the adults in their lives. However, the AAUW survey found that academic confidence and feelings of importance within one's family outranked

Women NEED encouragement, and this encouragement has to start at home; parents need to value a science career for their daughters. Approval is a very important part of most young women's lives — approval and self-esteem. We find that a little encouragement helps build the self-confidence needed to get over some barriers. The best encouragement, though, is from one's peers, be they male or female.

France Anne Cordova
Pennsylvania State University

France Cordova is the head of the astronomy and astrophysics department at Penn State University. She is best known for her research on compact x-ray sources, and discovered a new class of soft x-ray pulsations from dwarf novae and x-ray emissions from cataclysmic binary stars.

Courtesy Penn State University.

30

acceptance by one's peers. The survey also found that young women become discouraged because of the attitude of adults, including their teachers, that women cannot do the things that they themselves believe they can. Teachers have a special opportunity to affect the self-esteem of female students since a young woman's feelings about her academic performance correlate very strongly with her relationship with her teachers. Young men's sense of self-esteem correlates with their sense of confidence in their abilities, and since society sends the message that males can do anything they put their minds to, boys end up with higher degrees of self-esteem by the end of adolescence than do girls.

For readers of *Mercury*, perhaps the most interesting result of the AAUW survey is the result that students who enjoy math and science tend to retain higher levels of self-esteem regardless of gender. Most students indicated they liked math and science, particularly at the elementary level: 81% of girls and 84% of boys in elementary school like math and 75% of girls and 82% of boys in elementary school like science. However, this enthusiasm drops as students get older: by high school only 65% of girls and 72% of boys like math and 63% of girls and 75% of boys like science. Even fewer of the adolescents who "like" math feel they are "good at math". Girls interpret their problems with math as personal failures whereas boys are more likely to see problems as a result of the subject material itself. However, those adolescents who do like math and science are more likely to prefer career occupations in which they use these subjects and therefore aspire to careers as professionals. In addition, students who like math and science have higher levels of self-esteem — they like themselves more, feel better about their school work and grades, consider themselves more important, and feel better about family relationships. Adolescent women who like math and science are more confident about their appearance and worry less about others liking them. They also are less likely to be dissuaded from pursuing the career they are interested in.

So what can we do to encourage our girls and improve their sense of self-esteem? AAUW currently is sponsoring Educational Equity Roundtables on the state and local levels to address this question. Some of the suggestions which have been proposed are

1) short-term, focused teacher training to acquaint teachers with the subtle ways that girls are discouraged in the classroom,
2) encouragement of partnership programs between schools and industry, universities, and community organizations to provide girls with extra encouragement and improved opportunities outside the classroom environment,
3) more parental involvement in their daughters' education and training of parents to encourage their daughters' aspirations,
4) inclusion of different teaching techniques in the classroom (such as cooperative learning projects, emphasis on logical thinking, etc.), and
5) better media coverage of female professionals who can serve as role models to young girls.

Times are changing — the AAUW study revealed that most young people assume that women as well as men will have careers outside the home and that women can enter professions which previously were held predominantly by men. The results of this survey will present challenges which educators and public policy makers will need to overcome as we prepare today's students to face the realities of the next century. ■

A 17-page summary of the AAUW report "Shortchanging Girls, Shortchanging America" can be obtained from AAUW Publications, 1111 Sixteenth Street, N.W., Washington, D.C. 20036-4873. The cost is $5 plus $2.50 shipping and handling. The full report and a 15-minute videotape on the subject are also available. For more information, write the AAUW at the above address, or call (202)785-7700.

Some of the most outstanding researchers and some of the most effective administrative leaders in astronomy are women. They are widely recognized for their work. Potentially, this establishes a good background climate for young people entering the field. However, in my view, many astronomers do not consciously consider the outstanding successes as representative of what women can do. There is a great deal of talk about encouraging women to enter astronomy and frequent declarations of support for women who aspire to reach the highest levels of our profession. But there are relatively few university departments where this talk is translated into important practical action. The result is that the percentage of women in senior positions in astronomy today is not significantly greater than it was 50 years ago. One of the key problems is that the people making the decisions regarding tenure or professional recognition are overwhelmingly men.

John Bahcall
Institute for Advanced Study

John Bahcall is President of the American Astronomical Society. He headed the Astronomy and Astrophysics Survey Committee for the National Academy of Sciences which published a blueprint for the path astronomy should take over the next decade, and was one of the prime movers behind the development of the Hubble Space Telescope. His research interests include solar neutrinos, quasars, and a variety of other theoretical problems.

Courtesy John Bahcall.

Discrimination in the Workplace:

Results of Two Recent Surveys and Some Recommendations

Jill Price
Bentley College

Jill Price is an assistant professor of physics at Bentley College. Her research interests include dwarf galaxies, star formation, and the extinction of starlight due to dust in different types of galaxies.

Recent studies have shown that many women astronomers feel there is significant discrimination and harassment against them in the astronomical workplace. Women comprise 11% of the members of the American Astronomical Society, up from the low of 7.9% in the 1972 AAS survey, but still lower than the high of 17% recorded in 1938. A survey sent by the AAS in 1990 to all its members (of both sexes) elicited responses from 41.6% of the 5300 members. The survey covered many areas, including sources of funding, job descriptions, publishing scientific articles and meetings attendance. The survey also contained a section on equal opportunity, which included questions about sexual discrimination. Coincidentally, at about the same time, I independently surveyed 548 female AAS members specifically about sexual harassment and discrimination; 19% replied. It is likely that those who responded felt most strongly about the subject, and may not be representative of women astronomers as a whole. The two surveys asked different questions but had some common findings.

The AAS questioned its members on whether they had ever witnessed discrimination in various situations astronomers normally confront. [See table below]. Fifty percent of the women, but only fifteen percent of the men, had witnessed discrimination against women. In fact, women reported having witnessesed or experienced discrimination in far greater percentages than any other minority group. Male and female individuals working side by side in the same office or university department may not interpret a situation in the same way.

Percentage of respondents who witnessed or experienced discrimination against women

	% of women	% of men
General social treatment	50	15
Promotions	34	9
Accommodation of special circumstances	34	8
Pay/fringe benefits	31	8
Tenure decisions	26	6
Hiring practices	37	14
Research opportunities	25	5
Accommodation of job mobility	16	3
Opportunities to give talks, etc.	18	2
Competition for institution resources	17	3
Administrative appointments	14	3
Admission of students to graduate programs	17	4
Nominations, elective offices, honor societies	13	2
Committee assignments	12	2
Competition for grants/fellowships	14	2
Teaching assignments	10	1
Prizes and awards	11	2
Access to research facilities	9	2

AAS Survey, 1990

One of the finest experiences of my life was my first trip to Chile to observe, and my first glimpse of the southern sky. The trip rekindled all my interest in astrophysics, telescopes, instrumentation — and the southern sky left me breathless. I wanted to spend the entire night sitting outside the dome, watching it go by.

This experience was unfortunately followed by one of my worst experiences. I came home after two and a half weeks feeling very guilty, and anxious to see my children, who were aged 1 and 4. After three days of almost no sleep I rushed in to see them, and the "regular" babysitter had left the kids with a "substitute" babysitter. This woman started screaming at me, telling me what a bad mother I was to leave the children when they were so young. She made me incredibly angry, and sad.

Kathy DeGioia Eastwood
Northern Arizona University

Kathy Eastwood's research is in the area of star formation, particularly the mass distribution of newly formed stars and how such stars interact with the interstellar medium.

Clearly there is a perceptual difference between men and women as to what constitutes sexual harassment and discrimination.

On my survey, I asked women if they would agree with a series of sentences about whether different types of discrimination and harassment had ever happened to them personally. The highest response rates were recorded for the following statements:

- I have withstood verbal harassment, insulting remarks, and treatment as a "second-class citizen" on the job. (49%)
- I am not taken as seriously as my male colleagues. (35%)
- Often, because I was not afraid to voice an opinion on subjects about which I was knowledgeable, I was accused of being "difficult", "vocal", or "having a strong personality". (27%)

Of the 108 respondents, 23% had been sexually propositioned on the job. Of the women who had not personally experienced discrimination or harassment, 38% knew someone who had.

This discrimination reported may partly explain the fact that fewer women are found at the top ranks of astronomy than their numbers would indicate. Only 7% of senior researchers and full professors are women, whereas 10% of astronomers over age 35 are women, and 8% of all those over age 40 are women. The lower percentage of women in high status jobs could result from discrimination or attrition (which could be related to discrimination).

Or perhaps women have only recently begun to advance through the astronomy pipeline (due, in part, to affirmative action programs) and have not had time to reach high-level jobs in large numbers. There are more women at lower ranks than there are overall (about 20% of post-doctoral astronomers are women) and fewer young women than older ones have experienced discrimination. These could be hopeful signs. However, women who have just entered the field may not have had sufficient time to encounter discrimination. It is also unclear how many of the women currently in low-status positions will advance later to high-status positions.

Fair treatment of women does not end with hiring them into positions. Many recent articles have argued that in order to truly make a difference in the composition of the scientific community, women must be made to feel comfortable *after* they get the jobs.

Respondents to my survey had some sensible suggestions on how this could all be accomplished:

1. Mentors and role models for women astronomers are desperately needed.
2. Men need to be educated — some may not even be aware of what they are doing when they practice discrimination. Education for women is also important so that they will not feel isolated or blame themselves if they are the victims of inappropriate treatment.
3. A grievance and punishment system should be put in place for individuals and/or institutions who are found guilty of discrimination or harassment.
4. More women should be invited to speak at astronomical meetings, professional and amateur. More women should be on telescope time allocation and grant funding committees.
5. The problems of two-career families should be addressed. On-site daycare and shared positions are two possibilities which were mentioned.

The current climate for women in astronomy has improved — but is still far from what it should be. Some attempts are made by universities and observatories to reduce the bias in the hiring and promotion of women astronomers. However, with all the excellent scientific work done by women astronomers, and with a lot of supporting talk and words by various organizations and institutions, most astronomy departments and observatories still have NO women, especially at the senior levels. There is still, unfortunately, a subconscious negative bias in the appointment and promotion of women astronomers, in their general evaluation, as well as in their selection for invited talks, awards, and the like. There is still a prevailing feeling that a woman has to achieve considerably more than a man in order to be judged equally. A larger number of women in role-model, senior level positions, where decisions are made, coupled with a better understanding by the general astronomical community — of both genders — of this issue, should improve the situation for women in astronomy.

Neta Bahcall
Princeton University

Neta Bahcall's research interests revolve around extragalactic astronomy and cosmology. She studies the large-scale structure of the universe, galaxy clusters and voids, the "missing mass" problem, and quasars.

Courtesy Princeton University.

All of these suggestions have merit and should be considered by the astronomical community. Other suggestions, found in a recent *American Scientist* (Sept/Oct 1991) article on women in science include:

1. De-emphasize SAT's as a basis for college admissions and scholarships, since they are thought to be biased against women.
2. Publicize *recent* findings that indicate there is very little measurable difference between male and female brains which would have any bearing on their ability to do science.
3. Fund intervention programs for long periods of time, because *getting* women involved in scientific fields and *keeping* them involved are both important goals.
4. Revise the tenure system at universities and colleges. Current research indicates that mothers are just as productive as fathers are, once their children are all older than ten. It is not fair to penalize women just because their productivity drops for a short period while their children are young, and it is not fair to tell them they should not have any children if they want to be scientists, especially when no such message is being delivered to male scientists. This opens the Pandora's Box of the "mommy track", but these are important issues, and we need to discuss them until solutions are found.

Clearly there are many courses of action which could be pursued to steer women into astronomical careers and keep them there. Once the number of women astronomers has risen above a certain level, perhaps this type of survey and articles like this will no longer be necessary. ■

A Male Perspective:

Not Equal, Not Yet

Geoffrey Clayton
CASA, University of Colorado

Geoffrey Clayton studies interstellar dust and how dust forms in a class of variable stars that show sudden, unpredictable drops in brightness known as R Coronae Borealis stars. He is co-editor of Status, the newsletter of the AAS Committee on the Status of Women in Astronomy.

I recently overheard a conversation between a male professor and a female graduate student. They were discussing her career plans which had to take into account her husband, a Ph.D. physicist. The graduate student mentioned that she had started out in nursing but had switched to astronomy. The professor responded that nursing would be a good career to fall back on because it was so transportable. It was a fairly innocuous comment. But it was a comment that he never would have made to a male graduate student. No male student would ever be advised to switch careers to accommodate the career of his wife. Ironically, the male professor in question is extremely politically correct, works to encourage women and minorities in astronomy, and is married to a professional. He would say that he treats male and female students the same. But he doesn't. This is the sex discrimination of the '90s. Gone is the overt discrimination often seen in the past. There are still some male astronomers who feel that women should not be in astronomy at all, but they are near retirement and have gone underground with their views. Most male astronomers, which means most astronomers since 80% are men, are sensitive '90s kind of guys. They believe in equal rights for women. They believe that they treat women the same as men. But they don't.

Part of the problem is that women are still fairly rare in most astronomy departments. They are a minority among the graduate students. They are almost unheard of as professors. The result is that male astronomers are not used to dealing with women on a professional basis except as secretaries. Their experience with women is as mothers, wives, sisters, girlfriends and daughters. And the tendency is for men to transfer their behavior in these relationships to women they meet at work. Men need experience working with women as their peers in order to learn how to relate to female astronomers as astronomers rather than as females. Another facet of this problem is that some men, having worked with only one female astronomer, will generalize her character to all female astronomers and this will color how they treat other female astronomers. Finally, there is pressure of a different kind on women. The four-to-one ratio of men to women in astronomy means that a single woman will be subject to a lot of romantic

---

At a dinner I attended recently where I was being honored as the A.S.P. President, a man sitting next to me started the conversation with "Is your husband an astronomer?"

Julie Lutz
Washington State University

Julie Lutz is Director of the Division of Astronomical Sciences at the National Science Foundation and President of the A.S.P. Her research focuses on planetary nebulae.

attention whether she wants it or not.

Part of this problem is societal, and not isolated to astronomy or science. Women still do not start out on an equal footing with men in the workplace. Employers prefer to hire married men and single women. This is because married women still must shoulder a much greater burden than married men. Very few marriages are truly a 50-50 arrangement. Even the most sensitive '90s guy does not take a leave of absence when his wife has a baby, does not do 50% of the household chores, and does not do 50% of the child rearing. Men have the option of how much or how little to do. Women generally do not. Many men are sensitive to this problem and are making sincere efforts to do their fair share of work in a marriage. One example of this is that many professional couples now try to find two good jobs in the same place. If one or both are astronomers, the situation is often very difficult because jobs are rare and offers may come from anywhere in the country. Finding two decent jobs in the same place is almost impossible.

Despite these obvious professional disadvantages that women suffer in the workplace, some male astronomers, like men in other professions around the country, feel that affirmative action programs are giving women an unfair advantage. Several female astronomers whom I know have had the experience of male astronomers telling them that they will have no problem getting a job because they are female. It is particularly galling for a woman who has had to fight hard to get a Ph.D. and establish a reputation as a good scientist, to have people consider her success to be due only to her sex. If this theory of women's unfair advantage were true, a high percentage of the women in astronomy would be in tenured jobs. Just the opposite is true.

There is hope that these problems will not last. In astronomy departments which have several female astronomers, the situation seems to be working well. The men see women as a normal part of their work and the women don't see themselves as alone or under a microscope. I think we've come a long way toward equality in the astronomical workplace in the last 30 or 40 years but it may be 30 or 40 more years before men and women can work side by side as true equals. ■

Nancy Roman at the control console for the OAO 3 satellite (nicknamed Copernicus*) in 1972.* Copernicus *carried a 0.8-meter ultraviolet telescope and three small x-ray telescopes into space. At the time, Roman was Chief of Astronomy Programs at NASA's Physics and Astronomy Programs Office. (Courtesy NASA)*

In the U.K. there seem to be more women research students and young post-docs than there used to be, but there is no perceptible increase at the senior levels. Where are they disappearing to? I suspect a number are lost to astronomy through trying to keep going on soft money while playing second fiddle to their husband's careers and/or raising children; their domestic commitments limit their mobility and weaken their position.

Jocelyn Bell Burnell
The Open University

Jocelyn Bell Burnell discovered pulsars in the late 1960s. She is currently the chair of the Department of Physics at the Open University, Great Britain's largest university.

Photo by Robin Scagell, circa 1975.

Women Worldwide in Astronomy

Deidre Hunter
Lowell Observatory
and
Vera Rubin
Carnegie Institution of Washington

Editor's Note: This article is reprinted from the January 1989 issue of *Status*, the newsletter of the American Astronomical Society's Committee on the Status of Women in Astronomy.

A special session on "Women Worldwide in Astronomy" was held at the 20th General Assembly of the International Astronomical Union on August 8, 1988. The purpose of the meeting, which was attended by about 200 women and men, was to focus attention on the problems that women astronomers face throughout the world. The goal was to gain an international perspective and to compare the problems

At Mt. Wilson, one day at lunch, I was bored listening to the 100" and 60" observers talking. No one can get up from the table until they leave. I went to stretch my arms at the table and accidentally pushed my chair away from the table. The day crew took that as a signal, allowing me as a woman, I guess, to rule the dining table etiquette, and I inadvertently dismissed the table.

Lucy McFadden
University of California at San Diego

Lucy McFadden studies the nature of comets, asteroids and meteorites in the solar system, trying to determine the relationship among them.

Courtesy Scripps Institution of Oceanography.

women face in different countries. This is a brief summary of the high points of the discussion.

The percentages of astronomers who are women varies from country to country but they are generally low. Among the staff working in astronomy in China one-third are women. However, at the higher levels less than 10% are women. In India, although women have historically played a role in other fields like writing, there have been few women in astronomy. Of 20 Ph.D. astronomers in South Africa, one is a woman and there are two women graduate students. In Japan there are 600 astronomers and graduate students. Of these there are only 4 women with Ph.D.'s (of which 2 have permanent positions) and 10 graduate students. In Scandinavia there is one female astronomer with a full-time, permanent job. There are more female astronomers, but they either have no jobs or are employed part-time. On the other hand, 20 of 50 astronomers in Egypt are women.

France has a very high percentage of astronomers who are women, about 30%. There are several reasons for this. First, historically universities in France have always been open to women at all levels. The universities became somewhat closed to women in the 15th century, but in the 20th century France was one of the few places that a woman could get a Ph.D. in physics. In other countries there is not such a tradition. In the U.S.S.R., for example, it was only after the revolution that women were admitted to universities. A second factor aiding women astronomers in France is that academic positions are tied to the person rather than to a specific place. This makes it easier for a couple to combine two careers and still live in the same place. Finally, child care is very good and easy to obtain. Children of working women can stay later at school; and, since the majority of women work, there is no stigma on the child who must stay later. In many other countries child care is not as easy to obtain, and the woman with a career is expected to do double duty. Nevertheless, even in France there are problems. The percentage of women in astronomy has been declining recently, and the percentage of women in senior-level positions is lower than that overall in astronomy. As the salary-class goes up, the percentage of women decreases.

Women who do become astronomers find that they must work against prejudices. Work by women is often rated lower than that by men. Today women may get jobs in the physical sciences that would have been denied them in the past, but they may not get fair access to laboratory space and equipment and may be promoted more slowly than men. In India until recently women were not allowed to observe at night. Men are preferred in hiring and advanced faster, and women must endure an atmosphere in which they receive very little respect. In Mexico discrimination is not overt, but there is again a reluctance by men to appoint women to jobs with responsibility. A survey of papers and salaries of women astronomers in Latin and South American countries showed that women publish as much as men but earn lower salaries.

Prejudices within society also work to prevent women from becoming astronomers and make it harder if they do. In Mexico the expectations for women are different, and discrimination is evidenced in education, games, and responsibility at school and at home. Professionally, women have the problem of not being able to interrupt their careers to have children. In India women often disappear from astronomy after getting their Ph.D.'s because the social pressure to marry is very high. Many marry other scientists and then have the trouble of finding two jobs in one location.

In South Africa social pressures are probably largely responsible for discouraging women from going into science. First, women are regarded as secondary employees because women's primary function is considered to be caring for a family. The view that women belong in the home is reinforced through advertising and legislation. For example, there is no maternity leave. Second, sciences such as physics and engineering are considered to be "men's jobs." In addition, a shortage of science teachers and a lack of female role models discourages girls from following science careers.

Slowly the situation is changing; one can find distinguished women astronomers at higher-ranking positions. Acceptance of women on an equal footing, however, will

Carolyn Porco, as head of a Voyager *team that studied planetary rings, announces the discovery of the faint, tenuous rings of Neptune at a* Voyager *press conference in August 1989. (Photo by Lori Stiles)* come slowly as more and more young women enter the field. The entrenched, and often unconscious, prejudices that women face now will erode only if the task is tackled from the beginning at the educational level. To change the situation, women should promote science among young girls through their own visibility. ■

Deidre Hunter studies star formation in irregular galaxies, looking for differences in star formation in irregular galaxies versus spiral and elliptical galaxies. Vera Rubin studies the dynamics of galaxies and their large-scale motions. Her work on spiral galaxy rotation curves proved that tremendous amounts of matter exists in a form that is not detected by telescopes, the so-called "dark matter."

Ruth Peterson prepares the spectrograph on the Kitt Peak National Observatory 4-meter telescope for a night's observing. Peterson studies the chemical composition of old stellar populations, looking for relations between the composition and the positions and movements of the stars. (Courtesy NOAO)

I think slowly, very slowly, women are gaining more acceptance. There is a noticeable difference in grad school itself, where the number of women students has grown significantly. The greater presence of women in managerial positions everywhere has made it easier for women to gain access to administrative positions in astronomy. The director of the National Optical Astronomy Observatory is female. The head of astronomy at NSF is female. The head of the Institute of Geophysics and Planetary Physics at Lawrence Livermore National Laboratory is female. Slowly the visibility is making a difference.

I think if you came back in 100 years, you would see the number of women even higher and the total contribution of women larger than they are today. However, I am not sanguine that the activity of the sexes will ever be exactly equal because of women's extra dedication to children and family, which I see putting an extra burden (and also extra rewards) on them indefinitely into the future. This asymmetry between women and men is deeply ingrained and likely to be very persistent.

Sandra Faber
University of California at Santa Cruz

Sandra Faber's research has revealed many details of the large-scale structure of the universe, including the existence of a "Great Attractor," an immense concentration of mass 150 million light years away in roughly the direction of the constellation Centaurus that is pulling the Milky Way and its neighboring galaxies toward it.

Photo by Don Fukuda, UCSC.

Gillian Knapp's Advice to Young Women Interested in Astronomy as a Career

Gillian Knapp
Princeton University

Gillian Knapp studies the interaction between interstellar gas and stars in galaxies through observations at radio and infrared wavelengths. She wants to determine how those interactions influence galactic evolution and the properties of galaxies. (Photo courtesy Princeton University)

1. Work on scientific problems is driven by many things, but the most important is a passion for science. If you've got it, don't let anyone talk you out of doing what you want to do.

2. Learn lots of physics. Always work on problems that are a bit harder than you think you can do. Also, hone your skills at mathematics, computing, and hardware.

3. Know yourself very well. For people who belong to groups which are routinely discriminated against, it's very important when one encounters difficulties (and successes, too) to be able to do a reasonable job of disentangling one's own contribution from those of others.

4. Know what you want out of life. Our social structure hasn't evolved in response to changing employment and career patterns, and you will have to deal with the work/family conflict while almost all men don't. You can "have it all" if you want it but it won't drop into your lap.

I am encouraged by the tendency of some women to be particularly concerned about their female colleagues and their female students. I think this "networking" is one of the most positive and effective things we can do to promote the role of women in astronomy. It is a particularly crucial way to provide advice and support for young women. Women should invite each other to discuss informally the special problems they face. The special advice I would give to young women is to consult with other women in the field and find out from them what it is really like and what things are most helpful to do. Try to find out what the atmosphere is like at particular places and listen to the scuttlebutt about who is sympathetic to professional women and who is not.

John Bahcall
Institute for Advanced Study

5. If you can't stand to be told that "you only got this job/prize/grant/influential committee appointment because you're a woman" then don't become a scientist today. No matter whether such statements are "true" or not, you'll hear plenty of them. You'll also hear a lot about how women aren't cut out to be scientists, and may even hear various psychological "explanations." Pay no attention to this sort of nonsense; every second spent being upset about such stuff is a second you're not thinking about your work.

6. Nobody likes to think that (s)he is prejudiced. The practical result is that it's sometimes difficult to know whom to trust. Actions speak louder than words. It's not necessarily true that female scientists are more trustworthy than males. So when you apply for graduate schools/postdocs/faculty positions, an important thing to look at is the department's record on graduating and hiring non-traditional people.

7. Behave decently, honestly, and with civility. You'll encounter a lot of the opposite. Think very carefully about what you're doing before you do it. (Some) aggressiveness and self-confidence are good things to have, and you should for instance not hesitate to insist that promises which have been made to you be kept. However, be careful not to let these qualities spill over into hostility and negative attitudes toward your colleagues, however great the provocation. We're among the lucky few who get to work on things we're really interested in, after all. ■

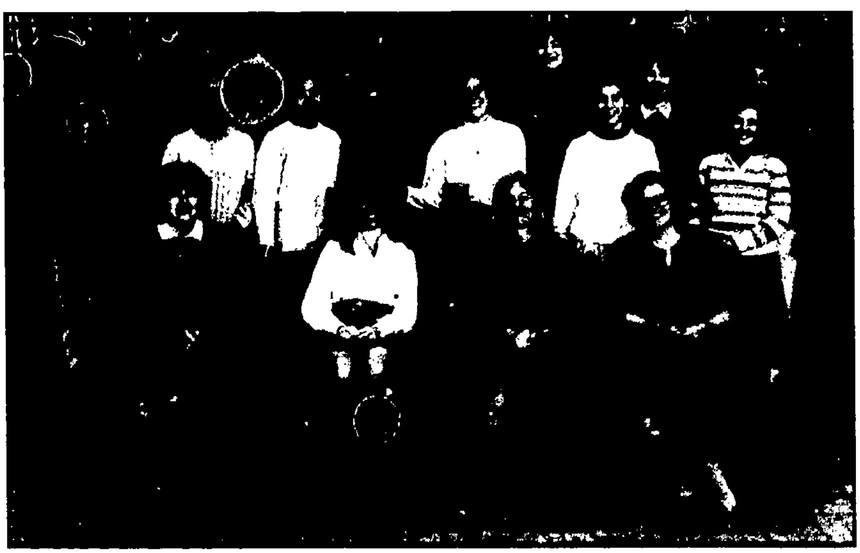
Forming a Local Women-In-Astronomy Group

Elizabeth M. Alvarez del Castillo
University of Arizona

Elizabeth Alvarez is a Research Assistant at Steward Observatory interested in using asteroids as resources. She is currently working on a database of all known asteroids, including their diameters, classification, brightness, etc.

In Tucson we have a large astronomical community and have formed a group of women in astronomy who meet for informal lunches to get to know other women in the field, to discuss specific issues, and to share experiences. At the request of *Mercury's* editors, I would like to explain how our group formed, why our "members" attend and want to continue the group, what we have done, and how our group has developed. Perhaps this will inspire groups like this in other parts of the country.

In the summer of 1990, a group of women in astronomy at Steward Observatory were invited to dinner by Susan Kleinmann, who was in Tucson on an NSF-sponsored visiting professorship for women. We were surprised at the number of topics that we wanted to discuss and at how useful it was to share our experiences. Talking to some of our female role models was helpful and was made easier by the relaxed setting away from our work environment. We felt that we should build on this and decided to get together again and to include the women astronomers at the University Lunar and



A few of the women in the Women in Astronomy Group in Tucson, Arizona. Astronomers in the group are variously from the National Optical Astronomy Observatories, Steward Observatory, and the University of Arizona's Lunar and Planetary Lab. Women pictured are, from left to right: (sitting) Suzanne Forgach, Elizabeth Alvarez, Karen Harvey, Karie Meyers, (middle row) Ann Bauer, Ying Wang, Shunbin Zhang, Sally Oey, Tamara Thompson, Beatrice Mueller, Caty Pilachowski, (back row) Angela Bragaglia, Teresa Bippert-Plymate, Wendy Erdwurm, Lindsey Davis, Roberta McMillan, Winifred Williams, and Grace Wolf. (Photo by Mark Hanna, NOAO)

Planetary Lab (LPL), the National Optical Astronomy Observatories (NOAO), the National Radio Astronomy Observatories (NRAO), and the Planetary Science Institute (PSI). That September we had an informal lunch and have continued these meetings on approximately a monthly basis. The group includes graduate students, post-doc's, faculty, staff astronomers, research astronomers, and administrators in astronomy.

After our first few lunches the women in our group said they were attending for a variety of reasons which include the following:

- for social reasons, to meet other women in the field
- to get back in touch with the issues facing women now and to work on what needs to be done to address them
- to find out how other women deal with problems in classes
- to learn ahead of time successful ways of dealing with potential obstacles or uncomfortable situations during interviews, on the job, etc.
- to discover how parents cope with the demands of family and career
- to meet role models and to discuss various career paths.

From the above list, we developed our first year's agenda. Our group sometimes meets with specific topics to discuss and sometimes leaves the hour free for open discussion. In addition to our informal lunches, we received support from Steward Observatory and the University of Arizona Affirmative Action Office to conduct a workshop entitled "Gender in the Work Environment." (Both men and women attended.) We have collected and discussed anecdotes from women on "chilly climates" that they have encountered on the job and in the classroom.

A meeting which we opened to fathers in the field to discuss family and childcare issues generated interest in a subgroup which will continue to address these issues. Another subgroup is following through on suggestions which came up during a meeting to discuss assault prevention and our safety concerns, since so many of us work alone late at night either in our office buildings or observing at telescopes. Recently we have instituted a series of "science plus" talks in which women astronomers talk about both their current research as well as how they got to where they are today and what they have learned along the way. In addition to these personalized talks, we have tapped the knowledge and experiences of the women in our group for such topics as "How to Write a Successful Grant Proposal."

When women are especially interested in pursuing a certain topic, they begin by bringing it up at one of our lunches to get feedback. Often a subgroup then forms to pursue the matter in more depth. Members of the larger group obtain updates on the subgroup's activities. This hub-and-spoke organization allows us to reach out in many directions while maintaining the hub or essence of a strong support group.

As we have discussed specific issues, two questions emerge again and again. The first is whether or not men should be invited to our sessions. How can we address issues realistically without input from half of the population and more than half of the astronomy community? Some of the women in our group have stated that they would not speak as freely on certain issues if men were present. Our answer is to mix the nature of our activities as much as we can so that everyone's needs are addressed. When we were discussing issues of gender in the workplace, for example, we had a round table discussion at one of our lunches in which the women present brought up situations which they had faced. From those collected anecdotes and with the help of some professionals in affirmative action, a subcommittee developed the workshop which we held for both men and women in our workplace. When we discussed childcare and family issues, we opened our informal lunch to any interested men and had a good attendance from fathers in astronomy as well as from some administrators who were interested in providing a more congenial work environment for parents. The concerns of our Women in Astronomy group initiated both of these sessions, but the input from the men was an important part of the overall success.

The second question which keeps emerging is how formal or informal to make our group. What the group has indicated is that the informal lunches establish a core which we need before we can reach out to pursue any formal issues. We need to have a few purely social events, such as our picnic and dinners away from work, to get to know the other women in the field. Then when we have our brown bag round table discussions, people will feel comfortable enough to discuss even the more personal issues, and we will have laid the groundwork for role model/mentor relationships as well as supportive friendships. We find that our group is meeting a need in the community by discovering and addressing a number of issues relevant to women in astronomy today. ■

Some 25 years ago at (almost) my first AAS meeting, after several minutes' pleasant conversation with a small, lively gentleman with an overpowering voice, I looked down at his name tag and uttered the heart-felt if inept phrase "My God. You're Martin Schwarzschild!" Quite recently at another meeting, I was talking with some local graduate students at the preconference dinner cocktail session, and one of them looked down at my name tag and reproduced phrase, screech, and (presumably) feeling of horror "Good God. You're Virginia Trimble."

Virginia Trimble
University of California at Irvine

Virginia Trimble's main research interests are white dwarf stars, supernovae and binary stars.

Photo by John Sanford.

Resource Organizations for Women in Astronomy

Committee on the Status of Women in Astronomy
American Astronomical Society

The Committee on the Status of Women in Astronomy is dedicated to improving the professional environment of women astronomers. The committee addresses such issues such as harassment, job opportunities, special fellowships for women, child care at meetings, having more women as colloquium speakers and invited speakers at conferences, and related matters. The committee is compiling lists of women astronomers and their fields of specialization, surveying graduate schools to assess their "women-friendly" environment, and bringing in guest speakers to address specific women's issues at AAS meetings. They organize "parent rooms" at meetings where audio can be piped into a room for parents who would like to listen to talks while attending to young children. An electronic bulletin board has been established so that the ideas and information can be shared weekly with those interested. To get on the list and/or send a message, use the e-mail address AASWOMEN@VASSAR.EDU. The committee chair is currently Debra Elmegreen.

Association for Women in Science

The Association for Women in Science, founded in 1971, works to improve the educational and employment opportunities for women in all science fields. AWIS publishes a newsletter, information on grants and employment opportunities, career guides, legislative updates, and educational material on a variety of subjects. With over 3500 members, AWIS monitors the status of women scientists and participates in national coalitions and organizations that work to expand the role of women in science. Local chapters sponsor monthly meetings, organize mentoring programs, promote science education in the schools and community, and participate as judges in science fairs. Contact: AWIS, 1522 K Street, N.W., Suite 820, Washington, D.C. 20005, (202)408-0742.

American Association of University Women

For more than a century, the American Association of University Women has promoted equity and education for women and girls. In communities across the country, 135,000 AAUW members work to help women and girls meet the demands of an increasingly complex society. The AAUW pushes for gender equity in the classroom, lobbies for issues such as civil rights, pay equity, family and medical leave, dependent care, and reproductive rights, supports women seeking judicial redress for sexual discrimination in higher education, and awards fellowships and grants to women. The AAUW's Educational Foundation administers the Annie Jump Cannon Award, presented annually to a woman for distinguished contributions to astronomy. For information about membership contact: AAUW, 1111 Sixteenth Street, N.W., Washington, D.C. 20036, (202)785-7700.

Boesgaard *from page 22*

The Keck Telescope and the Return of the Commute

The University of California was developing plans for a 10-meter optical/infrared telescope throughout the early 1980s, to be put on Mauna Kea. My husband went to join the Ten-Meter-Telescope (TMT) Project in Berkeley in 1984 and we began a commuter marriage again; this time I was based in Hawaii and he in California. And by then the phenomenon of dual-career commuting couples had become common enough that it had been the subject of study by social scientists. In January, 1985, Caltech and the W.M. Keck Foundation had entered the project, now called the W.M. Keck Telescope, and the headquarters moved to Pasadena in June, 1985. My husband was to be based there until late 1988 — much too long a time to commute! I managed to combine a sabbatical leave, a Guggenheim Fellowship, and a National Science Foundation Visiting Professorship for Women to spend nearly two years at Caltech.

And so my old dream of observing at Palomar with the 200-inch telescope finally came true. Modern telescopes are wonderful, but nothing holds the heart of astronomers (of my generation at least) as much as the 200-inch. I love the sound of the relays clicking, the wonder of the phantom that turns the dome, the absolute quiet of the night on the observing floor. The scientific environment at Caltech was everything I had imagined it to be, and with CCD (electronic detector) observations at Palomar, my research flourished. I spent much time exploring the "lithium-gap" that Michael Tripicco and I had found in the Hyades stars in the narrow mass range of 20 to 30% larger than the Sun; we had used the CFHT and the 88-inch telescopes on Mauna Kea for this discovery. At Palomar I could extend this work to other star clusters of different ages, metal content, place of formation, activity level, etc., to try to understand the cause of the phenomenon which occurred deep inside these stars.[5]

We have now been back in Hawaii for three years. My research interests seem to continually evolve and expand, in part because the technology evolves, enabling us to ask and answer ever more complex questions. And the W.M. Keck Telescope has been put together from the giant tinker-toy set it appeared to be on the dock in Kawaihae harbor to the remarkable giant telescope that was dedicated on November 7, 1991.[6]

There are so many enticing problems for me out there in our universe — about the evolution of stars, the chemical and dynamical history of our Galaxy, the formation and development of galaxies and clusters of galaxies, and of course the earliest moments of time, the first 15 minutes when hydrogen, helium, and lithium were created. The enchantment of astronomy and astrophysics is open-ended. ■

5. For futher discussion of this research, see the Nov/Dec 1990 issue of *Mercury* (pp. 182-185). — *Ed.*

6. For more on the Keck Telescope, see the article by J. Gustafson and W. Sargent in the Mar/Apr 1988 issue of *Mercury*. -- *Ed.*

Vera Rubin:

An Unconventional Career

Sally Stephens
A.S.P. Education Coordinator

Vera Rubin with part of her collection of antique globes. (Photo by Mark Godfrey)

Editor's Note: Vera Rubin, one of the country's best known and most respected women astronomers, was recently elected to the A.S.P. Board of Directors. Early in December 1991, while attending her first Board meeting, she spoke about her life and work with *Mercury* Assistant Editor Sally Stephens. Their conversation ranged from Rubin's youth through the experience of being the first woman to (legally) use the telescopes on Mount Palomar, to her pioneering work establishing the presence of vast quantities of "dark matter" in the universe.

Vera Rubin has an uncanny knack for asking questions that turn out to have profound implications for how we view the universe. In the early 1970s, dissatisfied with the ultra-competitive world of quasar research, she turned to what seemed a less controversial field, the problem of the rotation of normal spiral galaxies. She expected to find that the mass in a galaxy is distributed in the same way as its light, with most concentrated in the center. What she actually found was that there is considerable mass very far out from the center, out where few stars are visible. In fact, Rubin's work showed that everything we see — all the stars, star clusters, and glowing gas clouds — could amount to as little as 10% of the total mass of a large galaxy like our own Milky Way. The rest — as much as 90% — remains invisible, in some kind of "dark matter." During the past decade, figuring out what that dark matter is — dark stars, neutrinos, gravitinos, or some other exotic particle — has become one of the hottest topics in astronomy.

Vera Rubin grew up in Washington, D.C., and graduated from Vassar in 1948. She received a master's degree from Cornell University in 1951, and then followed her husband to Washington, D.C., where she received her Ph.D. from Georgetown University in 1954, following up on an idea suggested by the physicist George Gamow.

Since 1965, she has been a staff astronomer at the Carnegie Institution of Washington's Department of Terrestrial Magnetism (DTM), where she continues her research on galaxies. She has been very active in encouraging women and minorities to pursue careers in science. She holds honorary degrees from Yale and Harvard and is a member of the National Academy of Sciences and the American Academy of Arts and Sciences. She and her husband Robert still live in Washington, D.C., where they have raised four children, all of whom have Ph.D.'s in the sciences.

◆ ◆ ◆

MERCURY: How did you get interested in astronomy?

RUBIN: I got interested in astronomy as a child just looking at the sky. We moved to Washington when I was about 10 and we lived in the city. I had a bed immediately under a window that faced north. And I just started watching the stars. I could see the diurnal turning[1] of the stars and the Milky Way. I was fascinated and started reading [about astronomy], and built a very poor telescope, (laughs) a crummy telescope. I got a little lens from Edmund Scientific and a tube that linoleum came rolled in. You could see through it. I was pretty young but pretty interested and so next I tried to take pictures. I had a father who was an electrical engineer and really quite supportive. He thought I was kind of nuts but he helped me to do the things I couldn't do myself. I quickly learned I couldn't take pictures through that home-made telescope. The moon would move, not only due to the diurnal motion but motion of the telescope as well, I'm sure.

MERCURY: But you knew from the time you were quite young that you wanted to do astronomy.

1. The *diurnal* (daily) motion of the stars is caused by the rotation of the Earth. —*Ed.*

RUBIN: Yes, well from about that age. I knew I wanted to be an astronomer. I didn't know a single astronomer, male or female. Being a woman didn't bother me at all. I didn't think that all astronomers were male, because I didn't know. I didn't even know how you became an astronomer.

MERCURY: You went to Vassar for college.

RUBIN: I needed a scholarship and they gave me one. And I knew Vassar taught astronomy. I knew about the work of Maria Mitchell. So I went to Vassar and had a very, very nice classical education in astronomy and really learned a lot. It's not the way astronomy is taught nowadays. But I really got a lot out of it.

MERCURY: When you say it's not the way it's taught today, in what way was it different?

RUBIN: Well, I did a lot of classical dynamics[2]. I worked through Smart's books on galactic dynamics and stellar astronomy, calculating orbits on a desk calculator. I learned a lot of what now we would probably call practical astronomy, coordinate systems, and mathematical descriptions, more than astrophysics.

MERCURY: After graduating from Vassar in 1948, you started graduate school at Cornell.

RUBIN: I went to Cornell because I had gotten married and my husband was doing his Ph.D. there. At the time, Martha Stahr Carpenter was one of two people in the Cornell astronomy department; the other one was a navy navigator. She had just recently gotten a degree at Berkeley and she was very interested in galaxy dynamics. So I continued doing some galaxy dynamics with her. There were then radial velocities known for about 108 or 109 galaxies. For my master's thesis under her I asked the question — if you removed the [Hubble] expansion of the galaxies, did they have any [other] systematic motion.[3]

I remember she wrote to Milton Humason on the West Coast — this was 1949 or 1950. It was known among astronomers that Humason and his co-workers had many more redshifts which had not been published. He responded by saying they would be public pretty soon [in fact, it was six years before the redshifts were published]. So I was sort of told by observers that I should wait until there were more redshifts. And it was known that Princeton's Kurt Gödel was working on models of rotating universes and such, and so I was sort of told by theorists that I should wait. I guess I was impatient and so I went ahead with the paper on the galaxies.

MERCURY: You did find some systematic motions independent of the Hubble expansion.

RUBIN: I put every galaxy at the distance its apparent magnitude would put it. I took out the motion the expansion of the universe would contribute at that distance. I then took what was left — what we call the residual motion — and just plotted them on a globe. I presume none of this work would hold up today. I think the magnitudes of the galaxies were not good enough, and the velocities were probably not good enough.

I found that many of these galaxies defined a great circle on the sky, or roughly a circle, and that there were large regions of positive and negative values of residual velocity.[4] What in fact I really found was the supergalactic plane, although I entitled the paper "Rotation of the Universe."

MERCURY: But that was not well received?

RUBIN: The paper was rejected by both the *Astrophysical Journal* and the *Astronomical Journal*, but I did present it at an AAS meeting in Haverford in December 1950.

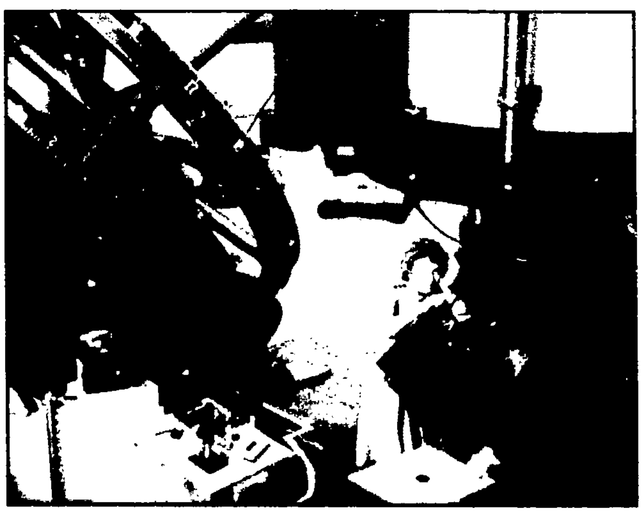
MERCURY: But you were vindicated later, weren't you? You found the same lopsided expansion in the 1970s when you were working with Kent Ford.

RUBIN: Well in principle, yes. The concept was a meaningful scientific

2. *Dynamics* is the study of how objects move under the action of forces, e.g., planets orbiting the Sun under the influence of the Sun's gravity, or stars orbiting the center of the Galaxy. — *Ed.*

3. The *Hubble expansion* is the motion of galaxies away from one another as a result of the expansion of the universe begun with the Big Bang. To understand these motions, astronomers measure the *radial velocity* of a galaxy, the component of its velocity away from us or toward us (*i.e.*, along the line of sight between the galaxy and an observer on Earth). — *Ed.*

4. Rubin had found that spiral galaxies of the same apparent brightness (and thus, presumably, the same distance) were moving away from the observer faster in one direction of the sky than in others. Her thesis would later help convince Gerard de Vaucouleurs of evidence for the existence of the Local Supercluster of galaxies. — *Ed.*



Vera Rubin working on the Carnegie image-tube spectrograph, which is attached underneath the Lowell Observatory's 72-inch telescope. The telescope's mirror is at the base of the white tube at upper right. This photo was taken in 1965. (Courtesy Vera Rubin) question,[5] as recent work by others on large- scale motions has indicated.

MERCURY: Then you went to Georgetown University.

RUBIN: We moved to Washington because my husband took a job there, and so I finished my graduate work at Georgetown.

MERCURY: You were going to graduate school, which is hard enough, and you were also married and raising a family. How did you do it?

RUBIN: It was the hardest thing in my life. I was at Cornell 2 or 3 years. I knew I wasn't going to be there long enough to get a Ph.D., so I didn't enter a Ph.D. program, but I did a lot of physics. I studied physics under Philip Morrison, Richard Feynmann, and Hans Bethe. I did a lot of coursework. I had our first child just as I was finishing that. I actually took my master's orals just a couple weeks before I had the child.

So I had a masters and I knew galactic dynamics and I knew some physics. And then I entered Georgetown to do a [Ph.D.] thesis and I got connected with George Gamow, who was a professional colleague of my husband's.[6] Ralph Alpher and Bob Herman who had been working with Gamow on Big Bang cosmology were colleagues of my husband's. Gamow asked me a very interesting question and I decided to try to answer it as a Ph.D. thesis.

MERCURY: And that was...

RUBIN: The single question he had asked me was whether there was a scale length in the distribution of galaxies.[7] And I got hold of Harvard galaxy counts on the sky and I applied a two-point correlation analysis to it. So my entire Ph.D. work really consisted of a single correlation analysis, something you would now do on a computer in minutes. Although in those days it was a messy job getting the data together. In the late 1960s, the Japanese applied correlation techniques to the distribution of galaxies, and then Jim Peebles started in the 1970s.

MERCURY: There are a lot a women astronomers who are trying to juggle family and career. You've been successful both in your career and with your family. Do you have any advice for them?

RUBIN: Well, I guess the only advice I would have is just sort of muddle through. It gets easier. The most important thing of course, and I was truly blessed, is to marry the right man. And I don't say that lightly because it's very easy for a marriage to suffer and even not to survive, if one is really, *really* dedicated to anything, including astronomy. I had the advantage that my husband was as dedicated to his physics as I was to my astronomy, but that we also both were enormously interested in having a family and raising the children. For many, many years, our lives consisted of nothing but our research and our family. The children really benefited because they had a very active father who helped raise them. And it's not all disadvantages.

If you are very, very busy, you don't have to pretend you aren't. I always needed help, and so running the house was always everybody's job. I was very outspoken when I was raising the children by informing them as often as necessary that I was not the maid. And we also had the great fortune of living in a very large old house in Washington so everybody had lots of space; that really helped. The kids had their rooms and I never cared what they looked like. We have lots of large tables. We have a very large table in the dining room. We have a very large table in the breakfast room. We have a little room with a large table and my husband used to always humorously say that there would always be a space on one of the tables where we could eat. Things were always spread out on those tables. I did a lot of my work at home. So having a family and career was very hard, but it's do-able.

MERCURY: You were the first woman to be permitted to observe at Palomar?

RUBIN: I was the first person to be permitted to *legally* observe at Palomar. Margaret Burbidge had observed there. Geoff [Burbidge, Margaret's husband, a

Vera Rubin measures shifts in galaxy emission lines from plates taken with the Carnegie image-tube spectrograph (taken sometime in the 1970s). Rubin used the measured emission-line shifts to calculate velocities of stars around the center of their galaxies. (Courtesy Vera Rubin)

5. The observation that many local galaxies are being pulled by something in the direction of Pegasus is now called the *Rubin-Ford effect*. — *Ed*

6. George Gamow, an eminent nuclear physicist with a strong interest in astronomy, helped establish the idea that the universe began with an explosive "Big Bang." — *Ed.*

7. Like her studies of large-scale motions of galaxies, Rubin's interest in the distribution of galaxies predated the current interest in the subject by about 20 years. A two-point correlation analysis determines the probability that a galaxy will have a second galaxy located at a specific distance from it. — *Ed.*

theorist, not an observer] had a Carnegie post-doc, and she must've just been given some research appointment. He was thus eligible for telescope time and she certainly went up and used the telescope, but she was not permitted to stay there. How often they let her, if it was frequent, I don't know but I suspect it was only a few times. But she had gotten up there, under his name. I was the first to observe under my own name.

MERCURY: One of the arguments that was made against having woman observers was that there weren't appropriate bathroom facilities.

RUBIN: That is correct.

MERCURY: When you observed, was that a problem?

RUBIN: (Laughs) No, but let me tell you the full story. I now work for the Carnegie Institution, and I have been reading its yearbooks, starting in 1902 when Andrew Carnegie formed the Carnegie Institution and work on Mt. Wilson Observatory began. He wanted to build a facility, and he says so, where the men would not be bothered by their families. So he called the living quarters on Mt. Wilson the "Monastery," built small rooms, and did not permit families. I certainly am not excusing anybody, but this problem wasn't something that originated in 1948 when Palomar's 200-inch building was built. Even today, there is only one toilet on the ground floor at Palomar and it says "Men."

I was asked actually by Alan Sandage in 1963-64 if I would like to apply for telescope time at Mt. Wilson or Palomar. I was sent a proposal form which said, printed, "Due to limited facilities, it is not possible to accept applications from women." And someone had penciled in "usually."

My first night on the mountain, it snowed. I had asked for 48-inch Schmidt time and I was given it. Olin Eggen was on the 200-inch. So he took me around the 200-inch, and with great majesty he opened the door and said, "This is the famous toilet." These days they've built a console room off the 200-inch where we work and there's a toilet there and it doesn't say anything on the door. About two years ago, I sort of got annoyed at this "Men" sign and I cut a little figure with a skirt and I pasted it up. It stayed for the four days I was there, but it wasn't there the next year.

MERCURY: Why were you the first? Was it your research that was found to be particularly deserving, did they like you, or was it just that the times had changed?

RUBIN: Let me *hope* that the work I was doing was interesting enough. I really had wanted to get back to a program in galaxy dynamics. It was what I knew and it was what I was interested in. And there was some very interesting work going on by Guido Münch who was observing stars in our own Galaxy toward the center, trying for the first time to deduce a rotation curve[8] of our own Galaxy, star by star. He picked stars and he tried from their spectroscopy to get their distance, and then assumed circular orbits. He had attempted to get rotation curves for the inner part of the Galaxy.

My usual interest was sort of orthogonal, or 180°, from others. I was interested in looking at the outside of the Galaxy and trying to deduce the rotation curve for the outer part of the Galaxy. I had done some of this with students at Georgetown, just using bright O and B stars from the literature. And ultimately I got to the point where I needed to make my own observations. I just couldn't find distant enough stars. And so in 1963, when Kitt Peak opened, I started using the 36-inch telescope to get orbital velocities of such stars near the anticenter of the Galaxy [the direction in the sky directly opposite the Galactic center] to extend the rotation curve of our own Galaxy. I had been attempting to get radial velocities of stars as far to the outside of the disc of our Galaxy as I could identify stars. That work was very well received; I think people found it interesting. Such a probe of the outside regions of the Milky Way had never really been done before in that fashion and I'd like to think that it was because of the research [that I was asked to apply for observing time at Palomar]. I clearly had demonstrated that I knew how to use a telescope.

MERCURY: More recently, people have given you a lot of credit for changing the way astronomers look at the universe. They say that 300 years ago astronomers thought that the universe consisted of what they saw. And you came along and all of a sudden the universe really consisted mostly of what you *can't* see. How did all of that come about?

RUBIN: This is a very, very long story. It's also really integrated with everything else I'd ever done. It started because I didn't like working on problems that many other people were working on and where I was constantly being besieged with questions about the work. I really wanted a problem that I could sit and do at my own pace, where I wouldn't be bothered.

It followed some very early work I had

8. A *rotation curve* is a plot of the orbital speeds of stars at different distances from the center of a galaxy. —*Ed.*

Announcing: Workshop on Women in Astronomy

The Space Telescope Science Institute is planning a workshop on the Status of Women in Astronomy, to be held at the Institute on September 8-9, 1992. The workshop will be geared toward the professional level, *i.e.*, graduate students, post-doctoral fellows, junior and senior astronomers, and administrators. The agenda will include discussion of the current status of women in the field, the particular challenges women face, and ways to improve the recruitment and retention of women in astronomy.

The organizing committee for the workshop includes Neta Bahcall, Peter Boyce, France Cordova, Laura Danly, Doug Duncan, Riccardo Giacconi, Anne Kinney, Julie Lutz, Goetz Oertel, Charlie Pellerin, Ethan Schreier, Meg Urry, and Sidney Wolff. For further details about the workshop, including registration information, please contact Barb Eller Jedrzejewski, Conference Coordinator, Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, (410)338-4836, or e-mail addresses: (decnet) STSCIC::ELLER, (bitnet) ELLER@stsci, (internet) ELLER@stsci.edu.

done on QSOs [quasars] with the image-tube spectrograph[9] when I first came to Carnegie. We had an instrument that could look very deep into the universe. We studied quasars for a year or two and I found it personally very distasteful. I just didn't like the pressure of other astronomers calling and asking me if I had observed this and if I knew what the redshift was. I didn't get to a telescope very often and it meant that I either had to give out answers that I was uncertain of, or say I hadn't done it and someone else would then go do it. I just decided that wasn't the way I wanted to do astronomy. I feel that I already have enormous numbers of internal pressures and I don't need external pressures on top of them. I really like to be left alone while I'm working.

So I decided to pick a program that no one would care about while I was doing it. But, at the same time, one that the astronomical community would be very happy with when I was done. So I decided to do a very systematic survey [of galaxy rotation curves]. My hope was that if I understood the dynamics of spirals (Sa's, Sb's, Sc's),[10] I would begin to understand why spiral galaxies came in different types; that I would learn more about the formation and evolution of spirals by just knowing their dynamics. And so I very carefully set up a fairly long-term program to observe about 60 galaxies, 20 of each kind. I started with the Sc's, of both low- and high-luminosity.

We found something surprising right away, really immediately, probably the first night, with our first few spectra. I did most of the observing with Kent Ford, who had built the spectrograph initially and who is really a superb instrumentalist. After our first observing run, we had about a dozen spectra and all the rotation velocities were high, all of them were a surprise.

MERCURY: What is it that you found that was so surprising?

RUBIN: Let me tell you what had always been expected. Just following Newton's Law, one expects that as you get farther and farther from a mass concentration, stars' orbital velocities will be slower and slower. This is true in the solar system, where the outer planets orbit much slower than the inner ones.

In the case of galaxies, we were estimating the mass by the luminosity we observed. And because there was so much luminosity in the center, it was assumed that most of the mass was at the center and [the amount of mass] would fall off quite rapidly [as you went out from the center]. So it was expected that ultimately we would get to regions in the galaxy where virtually all of the mass was interior, and the stars' velocities would follow the same pattern as they do in the solar system.

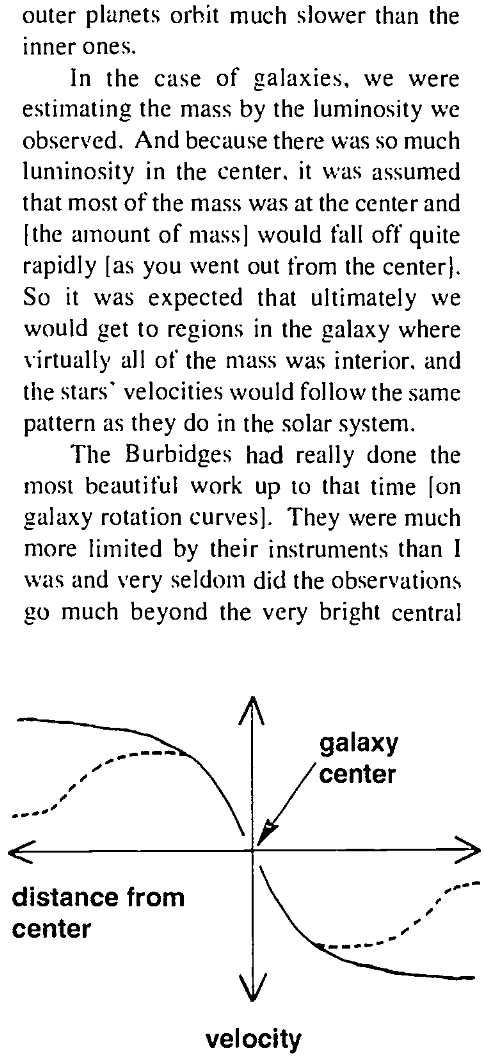
The Burbidges had really done the most beautiful work up to that time [on galaxy rotation curves]. They were much more limited by their instruments than I was and very seldom did the observations go much beyond the very bright central regions. And you could see the rise and you could see it sort of turn over and flatten out and then everyone just assumed the curve would fall beyond that point. So it was expected that when there was sufficiently sensitive instrumentation to observe far out in the galaxy, you would find that the rotation curve would rise, turn over and fall.

And so I decided to use the gain in sensitivity made possible by the image tube [to address this problem]. Most people used the image tube to go deeper into the universe — to work on quasars and on the most distant objects. I decided to just go completely across a galaxy and determine the dynamics all the way out. It just was apparent after the first few of these that what we were seeing were almost straight lines on the spectra.[11] You could see it by holding them up.

MERCURY: What did you think when you saw it? This was obviously not what you expected.

RUBIN: People keep asking me that. And I have to be really very honest. What I thought initially was just great delight in having gotten to the edge of the galaxy. You first want to see that it's do-able. You devise a program and you try something hard and you look and there's something there. And so what I remember most of all is just this incredible delight at the gorgeous spectra. They really were something! And then I started trying to figure out what was going on and my initial idea was totally wrong. I thought there must be some kind of a feedback mechanism. If a star orbited too rapidly, it was slowed down. And if it orbited too slowly, it was speeded up.

[It turns out that there is no feedback mechanism. The rotation curves did not turn over and fall because there is still a considerable amount of matter in the outer regions of galaxies, regions where few stars are visible. Since we cannot "see" light from this material, it has become known as "dark matter." Astronomers estimate that as much as 90-95% of all the matter in a

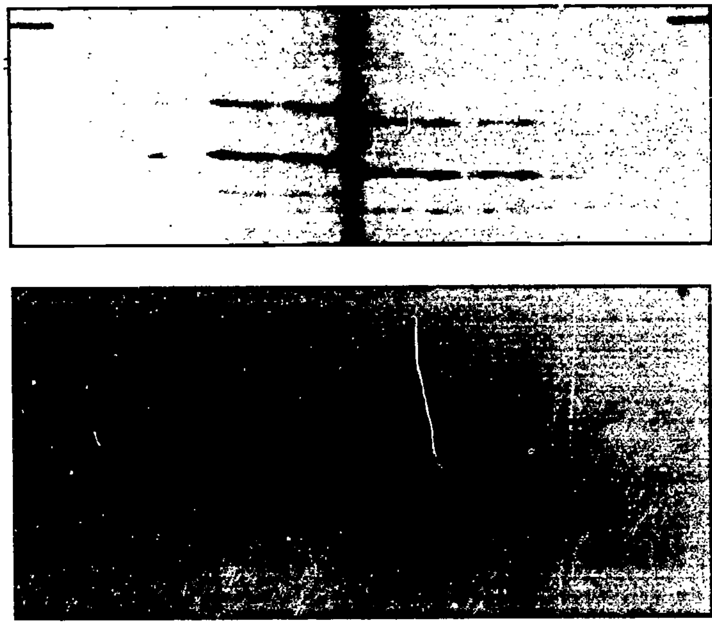


Astronomers expected the rotation curves of galaxies to rise until they reached the point where most of the mass of the galaxy was interior, and then turn over and decrease (dashed line). Planets in the Solar System, where almost all of the mass is inside the Sun, follow such a pattern, with Pluto moving much slower than Mercury. Rubin found that galaxy rotation curves do not turn over or decrease with distance from the center, as expected, but instead remain relatively flat once outside of the innermost regions (solid line).

9. The *image-tube spectrograph* that Rubin used was a state-of-the-art instrument (in the 1960s), built by Kent Ford, which, like a prism, spread the light from the stars out into their component colors which could then be analyzed. Because it used an electronic enhancer called an image-tube, it was much more sensitive than any earlier spectrographs and could be used to analyze the light from much fainter objects than had previously been possible. — *Ed.*

10. Spiral galaxies are classified according to their appearance. Those with tightly wound spiral arms and a prominent central bulge of stars are called *Sa galaxies*, whereas those with loosely wound spiral arms and a small central bulge are *Sc galaxies*. *Sb galaxies* are intermediate between the two. — *Ed.*

11. The straight lines on the spectra meant that the rotation curves far out from the center of the galaxy were flat. — *Ed.*



The spiral galaxy NGC 7541 (lower) was one of many studied by Rubin. The spectrum she obtained of the galaxy is shown above it (and at the same scale), with the horizontal axis representing distance from the galactic center (the thick vertical line). Light from the stars in NGC 7541 is spread out into its component colors vertically. The darkest horizontal line in the spectrum corresponds to emission from hydrogen gas, while the line above it comes from nitrogen. Because of rotation, half of the galaxy appears to be moving toward us, and half moving away from us, causing the shift in the emission lines on either side of the nucleus. The amount of shift is related to the orbital velocity at each point. As you move farther out from the center, the number of stars visible, and thus the amount of light decreases. But the emission lines appear flat out to the edge of the visible part of the galaxy where few stars are visible. Thus there must be a considerable amount of mass far from the galaxy's center, which does not shine and which we therefore cannot see. (Courtesy Vera Rubin)

galaxy is in the form of this dark matter (and no one is sure exactly what dark matter is). If the estimate is correct, the stars and nebulae we have studied for centuries because we see their light could represent only 5-10% of what is really there. — *Ed.*][12]

MERCURY: What was the reaction of astrononers to your rotation curves and the existence of dark matter implied by them?

RUBIN: I remember that it was not totally accepted by a lot of people. We scientists really change our ideas very slowly. We demand (I think we have to) an enormous amount of evidence before we will change our minds. And I remember some astronomers said, when we published this first dozen very flat rotation curves, "Well, that's because you've observed all the high-luminosity, brighter galaxies. Once you observe the lower luminosities, you'll find falling rotation curves." Actually it turns out that the lower mass, lower luminosity galaxies have a larger fraction of dark matter. Their rotation curves never really even turn, they just rise. Even with that evidence, of the first dozen or so rotation curves, it was not overwhelmingly accepted.

MERCURY: What finally convinced people? Was it seeing your spectra with their own eyes?

RUBIN: The change came from many directions. I think we still learn a lot from our eyes. And those spectra were so flat, and so really lovely, that you just had to show them to an astronomer and she would understand. Once the concept of a different gravitational potential[13] (one not defined by the light) surfaced, it was kind of shocking. The idea that when we thought we were studying the universe, we were just studying 5% of the universe was amazing. It took a while for everyone to come to terms with the fact that virtually everything we had ever learned in astronomy we had learned through photons[14]. There are a few exceptions — cosmic rays, a few neutrinos, a few things pass by that are not photons. But virtually everything we had ever learned about the universe, we had learned through photons. Suddenly we had to understand that no one ever promised us that all matter would radiate photons — that much of the cosmos could be dark. It does enlarge your vision.

MERCURY: It's interesting because you said that you had wanted to work by yourself on something, and yet your work turned dark matter from speculation into really big news, a hot topic.

RUBIN: That's right. Well, you know, we all change and, I have to confess, I have finally gotten into this... Sometimes I don't pursue directions that might be interesting just because I think they're too controversial. It has been a minor restriction but it really has been my own choice.

MERCURY: Some people have said, when talking about you, that you had a really unconventional career.

RUBIN: That's correct, that's very correct.

MERCURY: In what way?

RUBIN: Unconventional certainly in the early part. I did not go to any of the colleges or universities that traditionally turn out astronomers. I didn't study under any astronomers who were research astronomers of note. So I had to learn an enormous amount by myself. And I also was raising a family at the same time. And very happy doing both astronomy and raising a family.

So the kind of life I led was really very different from the kind of life that most graduate students in astronomy were doing. I think it did influence to a very large measure the kind of programs I chose to work on. Had I been at a real establishment institution, I probably would have just absorbed the knowledge that these topics were so speculative, that they were just not worth doing. Or worse than that — the ideas may have just been called wrong and not worth doing. I was not in a position

12. For more on dark matter, see the articles by W. & K. Tucker in the Jan/Feb and Mar/Apr 1989 issues of *Mercury*. — *Ed.*

13. *Gravitational potential* refers to the gravitational pull produced by a mass concentration, in this case the gravitational effects on stars caused by the presence of dark matter. — *Ed.*

14. *Photons* are discrete units of electromagnetic energy, including visible light, radio, infrared, and ultraviolet radiation. — *Ed.*

Women's Work *(1986)*

The following excerpt is from an article on women astronomers entitled "Women's Work" by Vera Rubin that appeared in the July/Aug 1986 issue of Science 86. *It is reprinted with the author's permission.*

Since the 1950s, opportunities for women in astronomy have increased, but serious problems have not disappeared. Women whose brilliance is apparent at an early age can study at prestigious undergraduate universities, be accepted to graduate schools, accomplish important research, and obtain university or observatory positions. But, as with their male counterparts, such brilliance is rare. The remainder suffer because of their small numbers.

A student who thinks she might like to be an astronomer will often enter a department where she will be the only woman student; there will be no women on the faculty. If fortunate, she will find a sympathetic advisor and congenial colleagues with whom to study. Even so, she will be treated differently from male students. One faculty member may proclaim openly that he doesn't want a woman to work with him. Her work will be scrutinized with a care that most of her male counterparts will be lucky enough to escape. She will stand out in everything that she does. And if she persists and obtains a degree, her advisor may well sit her down and suggest that she not set her sights too high in seeking a postdoctoral position.

This kind of gatekeeping also serves to limit opportunities. The letters of recommendation that her advisor writes will not be discriminatory but may be subtly different and tentative. If she is married, she may not receive job offers: "We thought her husband would not want to move" is the usual excuse. And when she goes to a meeting, she is likely to be the only woman attending.

Permanent jobs in astronomy are scarce and hard to get for young men and women alike. Affirmative action seems to have made few inroads in the filling of academic positions. It is common for an astronomy department to receive 100 or more applications for a job; usually no more than one or two of the candidates are women.

Women constitute only a tiny fraction of tenured professors of astronomy. I think this is in part because the field of astronomy is still so dominated by a male establishment. A single member of a department search committee who is reluctant to add a woman to his staff can have an enormous influence for many years. Cases have occurred in which an application list of many has been carefully narrowed down to three: two men and one woman, in that order. Following job offers to the top two, who decline the offer, the decision is then made to reopen the competition rather than offer the job to the third. Rarely does this happen when the top three candidates are male. Unfortunately, as the job market becomes even tighter, it is unlikely that the number of women in tenured academic positions will increase.

The saddest part, of course, is that only about one-fifth of the women who enter college intend to study science. Lack of support and encouragement at an early age has by then taken its toll. A young woman who enters graduate school to study science is a rare creature indeed, to be encouraged and supported. But instead, the colleges are often a part of the problem rather than a part of the solution.

In spite of these difficulties, women are becoming astronomers — and successful ones. They are asking important, imaginative questions about the universe and getting answers no less than their male colleagues. Only for the past 20 years or so have they been permitted to apply for telescope time on all telescopes — time being allotted on the basis of the excellence of the proposal. Now about one-third of the telescope time of the national facilities, which include Kitt Peak Observatory outside of Tucson, Arizona and Cerro Tololo Observatory in Chile, is assigned to women.

A cable that was sent to me in 1978 is a testament to that. "Dear Madame," it reads, "You might appreciate hearing that four women astronomers are observing on Cerro Tololo tonight, on the four largest telescopes! We are M.H. Urich, M.T. Ruiz, P. Lugger, and L. Schweizer." I hope the sky was very clear that night.

where I was ever told that or exposed to that kind of pressure. So I just went ahead on my own. I think it's also honest to say, that such an approach has a good side and a bad side. Its bad side is that the work was virtually unknown, ignored, or considered wrong. But I think there was at least some intellectual rationale for asking those questions even if they couldn't be answered at that time. It wasn't a bad way to work. I have no regrets.

MERCURY: Has it gotten better for women now than it was when you started out?

RUBIN: I think the answer is yes. I'm satisfied that it is improving. But it really is improving very, very slowly. It's partly because university academic departments are filled with people with tenured positions that don't change very often. It will be a long, long, *long* time (unless there is really some very positive action) before astronomy (and physics even more so) is not a man's world. It's going so slowly that at times it's hard to be optimistic.

MERCURY: What do you think it will take to make it better?

RUBIN: Well, it will take people wanting it to change. Or it will take a political climate that really believes in affirmative action, that really believes that opportunities ought to be made available equally to everyone. I think at the present time opportunities are not really made equally available. There are always enough men in positions of authority and power that are not enthusiastic about making opportunities available to everyone equally. And a few men in a department who don't want to work with women at all. The opportunities available for women are still fewer than the opportunities available for men.

MERCURY: Why do you think you have been successful as an astronomer — as a woman *and* an astronomer — while other women have not and have ended up dropping out.

RUBIN: That's not a fair question, because that's the kind of question we only ask someone who has been successful. There is a tragedy in that question and the tragedy is that there may be hundreds and even thousands of women who would have liked to have been astronomers and who would have made great astronomers and really never had the opportunity. They're the ones that ought to be asked what would have been necessary to make it possible for them to do astronomy. Sure, statistically, some people will succeed and maybe it's sheer luck. Maybe I was just at the right place at the right time, and was as good as the males around — as astronomers who were male — so I survived. But I don't know, it's hard to say. I think a good part of it is luck. I think a good part of it is being well enough prepared so you can take advantage of good luck when it comes along. And, for me, I think it's also been having a supportive husband and supportive family.

Vera and Bob Rubin (center) with their children (left to right) Karl, Judy Young, Allan and David, plus David's wife Michelle and assorted grandchildren. (Photo by Pat Lanza Field)

MERCURY: Your daughter, Dr. Judith Young, is also an astronomer, making you two about the only mother-daughter astronomer pair people normally can think of. Did she ask for any particular advice or did you give her any particular advice on astronomy as a career?

RUBIN: She, all of her high school days, had planned to study biology and chemistry. All of our children went through the Washington, D.C. public high schools. During her senior year in high school, I taught a college-level introductory course in astronomy. I just walked into the high school and volunteered my time. And by the end of that term, she decided she wanted to be an astronomer. I think that all these things she had grown up around just suddenly made sense to her, and must have looked appealing. She has done very well, but still she's had difficulties in her career that would probably not have faced a man at the same level at the same time. She was an undergraduate at Radcliffe, and her very young, very bright advisor suggested she go off and get married the first time she went to him with a problem. She was enrolled as a Ph.D. student when she got married and the faculty decided that she should terminate with a masters because she could not be very serious about being an astronomer if she was getting married. It's hard to say whether — this was in the late 1970s — a young man at the same time would have been hassled because he chose to get married. But she survived even so.

MERCURY: Is there any advice you would give to a young woman considering a career in astronomy?

RUBIN: Well, my advice is just not to give up. To just muddle through, to just get through. This is advice at the college level and the graduate level. You may meet an enormous number of hardships during the college days. I think many colleges, universities and graduate schools really still are not totally supportive of young women. Some are, just as some men are. There are some wonderful people in this world who do offer support to all kinds of people. But for those young women students who seem to be having a tough time, my advice would be, as I said, just not to give up. Not to feel that the problem is with them, but rather to have the confidence to feel that the problem is with the system. And if you can just get through, and get a degree, and get a job, you have a good chance of making it in the astronomical world.

MERCURY: You stuck with astronomy all these years. Is astronomy fun?

RUBIN: Oh, it's enormous fun. It's enormous fun. Every day is (laughs) fun. Observing is spectacularly lovely. Really, really quite inspiring. And I enjoy analyzing the observations, trying to see what you have, trying to understand what you're learning. It's a challenge, but a great deal of fun. It's not only fun, but a lot of it is just plain curiosity — this incredible hope that somehow we can learn how the universe works. What keeps me going is this hope and curiosity, this basic curiosity about how the universe works.

Possibly more than many people, I have really been privileged to have a job where I can do very much what I want. And that really means it's such a joy to get up and come to work. Many days I really don't have a very clear idea of what I'm going to be doing. I just sort of continue where the work seems to lead. And that, to me, is just a lovely way to work.

MERCURY: You're lucky to have found something that you enjoy so much.

RUBIN: That's correct. I think that probably one of the greatest blessings there is, is to really find every day such a joy. ■

For more on Vera Rubin's work and career, see the articles by and about her in the bibliography in this issue. We especially recommend the interview with her in the book *Origins* for a more extended perspective on some of the issues and projects discussed above. — *Ed.*

Women in Astronomy:

Andrew Fraknoi
Astronomical Society of the Pacific

General References on Women in Astronomy

Alic, M. *Hypatia's Heritage: A History of Women in Science from Antiquity to the Late Nineteenth Century*. 1986, Women's Press.

Davis, H. "Women Astronomers" in *Popular Astronomy*, May and June 1898; vol. 6, p. 129 and p. 211.

Gornick, V. *Women in Science*. 1983, Simon & Schuster. Not much astronomy but a good general introduction.

Flam, F. "Still a 'Chilly Climate' for Women?" in *Science*, vol. 252, p.1604, June 21, 1991.

Fins, A. *Women in Science*. 1979, VGM Career Horizons.

Haas, V.B. & Perucci, C.C., eds. *Women in Scientific and Engineering Professions*. 1984, U. of Michigan Press.

Jones, B. & Boyd, L. "A Field for Women," chapter 11 of *The Harvard College Observatory, 1839-1919*. 1971, Harvard U. Press.

Kass-Simon, G. & Farnes, P., eds. *Women of Science: Righting the Record*. 1990, Indiana U. Press. Contains chapter on female astronomers.

Kidwell, P. "Three Women of American Astronomy" in *American Scientist*, May/June 1990, p. 244. (On Mitchell, Cannon, and Payne-Gaposchkin)

Kidwell, P. "Women Astronomers in Britain 1780 - 1930" in *Isis*, Sep. 1984; vol. 75, p. 534.

Klumpke, D. "The Work of Women in Astronomy" in *Observatory*, Aug. 1899 (vol. 22, p. 195.)

Krupp, E. C. "Astronomical Msings" [sic] in *Griffith Observer*, vol. 39, p. 8, May 1975.

Lankford, J. & Slavings, R. "Gender and Science: Women in American Astronomy 1859-1940" in *Physics Today*, Mar. 1990, p. 58.

Lightman, A. & Brawer, R. *Origins: The Lives and Worlds of Modern Cosmologists*. 1990, Harvard U. Press. (Includes interviews with Vera Rubin, Margaret Geller, and Sandra Faber.)

Mack, P. "Straying from Their Orbits: Women in Astronomy in America" in Kass-Simon, G. & Farnes, P., eds. *Women of Science*, 1990, Indiana U. Press.

Mack, P. "Strategies and Compromises: Women in Astronomy at Harvard College Observatory" in *Journal for the History of Astronomy*, vol. 21, p. 65 (1990).

McKenney, A. "What Women Have Done for Astronomy in the United States" in *Popular Astronomy*, vol. 12, p. 171 (1904).

Nelson, D. "Daughters of the Sky: A Brief History of Women in Astronomy" in *Griffith Observer*, March 1983, p.2.

Ogilvie, M. *Women in Science* (A Biographical Dictionary). 1986, MIT Press.

Reed, H. "Women's Work at the Harvard Observatory" in *New England Magazine*, vol. 6, p. 174 (1892).

Richardson, R. "Astronomy — The Distaff Side" in *Leaflets of the Astronomical Society of the Pacific*, #181, March 1944.

Rizzo, P. "Early Daughters of Urania" in *Sky & Telescope*, Nov. 1954, p. 7.

Rossiter, M. *Women Scientists in America*. 1982, Johns Hopkins U. Press.

Rubin, V. "Women's Work: Women in Modern Astronomy" in *Science 86*, Jul/Aug. 1986, p. 58.

Siegel, P. & Finley, K. *Women in the Scientific Search: An American Bio-bibiliography*. 1985, Scarecrow Press.

Spradley, J. "Women and the Stars" in *The Physics Teacher*, Sep. 1990, p. 372.

Warner, D. "Women Astronomers" in *Natural History*, May 1979, p. 12.

Widnall, S. "Voices from the Pipeline: Women in Science" in *Science*, vol. 241, p. 1740 (30 Sep. 1988)

Zahm, J. "Women in Astronomy" in *Woman in Science*. 1913, D. Appleton, (pp. 167-196)

Zuckerman, H., Cole, J., & Bruer, J. *The Outer Circle: Women in the Scientific Community*. 1991, W.W. Norton. Includes an extensive interview with Harvard astronomer Andrea Dupree.

References on A Few Specific Women Astronomers

Baliunas, Sallie

Flamsteed, S. "Star Spots: The Work of Sallie Baliunas" in *Discover*, Dec. 1991, p. 29.

Bell Burnell, Jocelyn

Bell Burnell, J. "Little Green Men, White Dwarfs, or What?" in *Sky & Telescope*, Mar. 1978, p. 218.

Greenstein, G. "Neutron Stars and the Discovery of Pulsars" in *Mercury*, Mar/Apr. 1985, p. 34 and May/June 1985, p. 66.

Reed, G. "The Discovery of Pulsars: Was Credit Given Where It Was Due" in *Astronomy*, Dec. 1983, p. 24.

Burbidge, Margaret

Arp, H. & Fraknoi, A. "The Award of the 1982 Bruce Medal to Margaret Burbidge" in *Mercury*, Sep/Oct. 1982, p. 154.

Burbidge, M. "Adventure into Space [Presidential Address to the American Association for the Advancement of Science]" in *Science*, vol. 221, p. 421 (1983).

Reed, J. "A Great Woman Astronomer Leaves England Again" in *Smithsonian*, Jan. 1974, p. 34.

Rubin, V. "E. Margaret Burbidge: [AAAS] President-Elect" in *Science*, vol. 211, p. 915 (1981).

"The Stargazer" in *Time* magazine, Mar. 20, 1972, p. 38.

Cannon, Annie

Bok, P. "Annie Jump Cannon 1863 - 1941" in *Publications of the A.S.P.*, Jun. 1941, vol. 53, p. 168.

Emberlin, D. *Science: Contributions of Women*. 1977, Dillon Press. Includes a section on Cannon, pp. 7-27.

Merrill, P. "Annie Jump Cannon" in *Monthly Notices of the Royal Astronomical Society*, vol. 102, no. 2, p. 74 (1942).

Payne-Gaposchkin, C. "Miss Cannon and Stellar Spectroscopy" in *The Telescope* (predecessor to *Sky & Telescope*), vol. 8, p. 63 (1941).

Veglahn, N. "Annie Jump Cannon, Astronomer" in *Women Scientists*, 1992, Facts on File.

Welther, B. "Annie Jump Cannon: Classifier of the Stars" in *Mercury*, Jan/Feb. 1984, p. 28.

Faber, Sandra

Lightman, A. & Brawer, R. "[Interview with] Sandra Faber" in *Origins*, 1990, Harvard U. Press.

Pasachoff, J. "Interview with Sandra Faber" in

A Bibliography

Ruth Freitag

Library of Congress

Journey through the Universe. 1992, Saunders.

Fleming, Williamina

Cannon, A. "Williamina Paton Fleming" in *Astrophysical Journal*, vol. 34, p. 314 (1911).

Rolston, W. "Mrs. W. P. Fleming" in *Nature*, vol. 86, p. 453 (June 1, 1911).

Spradley, J. "The Industrious Mrs. Fleming" in *Astronomy*, July 1990, p. 48.

Furness, Caroline

"Caroline Ellen Furness" in *Monthly Notices of the RAS*, vol. 97, p. 272 (Feb. 1937).

Makemson, M. "Caroline E. Furness" in *Publications of the A.S.P.*, vol. 48, p. 97 (Apr. 1936).

Geller, Margaret

Abell, G. *et al.* "Interview with Margaret Geller" in *Realm of the Universe*. 1991, Saunders.

Geller, M. "Mapping the Universe: Slices and Bubbles" in *Mercury* May/June 1990, p. 66.

Goldsmith, D. "Mapping the Universe", Chapter 5 of *The Astronomers*. 1991, St. Martin's Press.

Lightman, A. & Brawer, R. "[Interview with] Margaret Geller" in *Origins*. 1990, Harvard U. Press

Herschel, Caroline

Lubbock, C. *The Herschel Chronicle*. 1933, Cambridge U. Press. Family chronicle of William and Caroline, by his granddaughter.

Ogilvie, M. "Caroline Herschel's Contributions to Astronomy" in *Annals of Science*, vol. 32, p. 149 (1975)

Turner, A.J. "Some Comments by Caroline Herschel on the Use of the 40-ft. Telescope" in *Journal for the History of Astronomy*, vol. 8, p. 196 (1977)

Hogg, Helen Sawyer

Morrison, D. & Fraknoi, A. "1983 ASP Award Winners: Klumpke-Roberts Award to Helen Sawyer Hogg" in *Mercury*, Nov/Dec. 1983, p. 185.

Yost, E. *Women of Modern Science*. 1959, Dodd, Mead: pp. 31-47 are on Helen Hogg.

Huggins, Margaret

Newall, H. "Dame Margaret Lindsay Huggins" in *Monthly Notices of the RAS*, vol. 76, p. 278 (Feb. 1916).

Richardson, R. "Lady Huggins" in *The Star Lovers*. 1967, Macmillan.

Klumpke Roberts, Dorothea

Aitken, R. "Dorothea Klumpke Roberts" in *Publications of the A.S.P.*, Dec. 1942, vol. 54, p. 217.

Bracher, K. "Dorothea Klumpke Roberts: A Forgotten Astronomer" in *Mercury*, Sep/Oct. 1981, p. 139.

Klumpke, D. "A Night in a Balloon" in *Century Magazine*, vol. 60, p. 276 (1900).

Reynolds, J. "Dorothea Klumpke Roberts" in *Montly Notices of the RAS*, vol. 104, no. 2, p. 92 (1944).

Weitzenhoffer, K. "The Triumph of Dorothea Klumpke" in *Sky & Telescope*, Aug. 1986, p. 109.

Leavitt, Henrietta

Bailey, S. "Henrietta Swan Leavitt" in *Popular Astronomy*, vol. 30, p. 197 (Apr. 1922).

Mitchell, H. "Henrietta Leavitt and the Cepheid Variables" in *The Physics Teacher*, Mar. 1976, vol. 14, p. 162.

Richardson, R. "Henrietta Leavitt" in *The Star Lovers*. 1967, Macmillan.

Maury, Antonia

Hoffleit, D. "Antonia Maury" in *Sky & Telescope*, Mar. 1952, p. 106.

Mitchell, Maria

Kendall, P. *Maria Mitchell: Life, Letters, and Journals*. 1896, Lee and Shepard.

Kohlstedt, S. "Maria Mitchell and the Advancement of Women in Science" in Abir-Am, P. & Outram, D., eds. *Uneasy Careers and Intimate Lives: Women in Science 1789-1979*. 1987, Rutgers U. Press.

Wright, H. *Sweeper in the Sky: The Life of Maria Mitchell*. 1950, Macmillan.

Payne-Gaposchkin, Cecilia

Haramundanis, K., ed. *Cecilia Payne Gaposchkin: An Autobiography and Other Recollections*. 1984, Cambridge U. Press.

Kidwell, P. "Cecilia Payne-Gaposchkin: Astronomy in the Family" in Abir-Am, P. & Outram, D., eds. *Uneasy Careers and Intimate Lives: Women in Science 1789-1979*. 1987, Rutgers U. Press.

Smith, E. "Cecilia Payne-Gaposchkin" in *Physics Today*, June 1980, p. 64.

Whitney, C. "Cecilia Payne-Gaposchkin: An Astronomer's Astronomer" in *Sky & Telescope*, Mar. 1980, p. 212.

Ride, Sally

Blacknall, S. *Sally Ride: America's First Woman in Space*. 1984, Dillon Press. A book for youngsters.

Rubin, Vera

Bartusiak, M. "The Woman Who Spins the Stars" in *Discover*, Oct. 1990, p. 88.

Lightman, A. & Brawer, R. "[Interview with] Vera Rubin" in *Origins*. 1990, Harvard U. Press.

Rubin, V. "Women's Work: Women in Modern Astronomy" in *Science 86*, Jul/Aug. 1986, p. 58.

Sitterly, Charlotte Moore

Morrison, N. & Fraknoi, A. "The Award of the 1990 Bruce Medal to Charlotte Moore Sitterly" in *Mercury*, Nov/Dec. 1990, p. 179.

Tousey, R. "The Solar Spectrum from Fraunhofer to Skylab: An Appreciation of the Contribution of Charlotte Moore Sitterly" in *Journal of the Optical Society of America, Series B*, vol. 5, p. 2230 (Oct. 1988).

Tarter, Jill

Abell, G. *et al.* "Interview with Jill Tarter" in *Realm of the Universe*. 1991, Saunders.

Swift, D. "[Interview with] Jill Tarter" in *SETI Pioneers*. 1990, U. of Arizona Press.

Tarter, J. "Searching for Them: Interstellar Communication" in *Astronomy*, Oct. 1982, p. 10.

Tinsley, Beatrice

Faber, S. "Beatrice Tinsley" in *Physics Today*, vol. 34, p. 110 (1981).

Hill, E. *My Daughter Beatrice*. 1986, American Physical Society. ■

MERCURY

The Journal of the Astronomical Society of the Pacific

Vol. XXI, Number 1 • January / February 1992

Special Issue on Women in Astronomy

*ON OUR COVER: **Women astronomers of the past and present.** Clockwise from upper right: Annie Jump Cannon dressed to accept an honorary degree of Doctor of Science from Oxford University in England, the first woman to be so honored. (Courtesy Harvard College Observatory); Sandra Faber in the control room of the 120-inch telescope at the University of California's Lick Observatory circa 1980. (Courtesy Sandra Faber); Women students at Vassar College in 1878. (Courtesy Vassar College Library); A group of staff members at the Harvard College Observatory in 1925 (Courtesy Harvard College Observatory); Nancy W. Boggess, Deputy Project Scientist for the Cosmic Background Explorer satellite (COBE), examines the COBE test dewar in a laboratory at the NASA Goddard Space Flight Center. (Courtesy NASA/Goddard); France Cordova, professor and head of the Astronomy and Astrophysics Department at Pennsylvania State University, presents a theoretical problem to an astronomy honors class. (Courtesy Penn State University)*

Mercury
The Journal of the Astronomical Society of the Pacific

J/F

When you write to the Society, please include the 6-digit "ASP" number ➜ directly above your name.

Mercury (ISSN 0047-6773) is published bimonthly by the Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112. **POSTMASTER:** Send all address changes to the above address.

Second class postage paid at San Francisco and additional mailing offices. Postal identification number 984880.

The Astronomical Society of the Pacific is an international non-profit scientific and educational organization, founded in 1889, that works to increase the public understanding and appreciation of astronomy.

The Society publishes:

- *The Publications of the A.S.P.*, a technical journal of refereed research reports and review articles;
- *Mercury*, a nontechnical journal intended for the general reader, as well as teachers and students of astronomy;
- *The Universe in the Classroom*, a newsletter on teaching astronomy in grades 3 - 12; available without charge to teachers who request it on school stationery.

Members in North America also receive the Abrams Planetarium monthly Sky Calendar.

Membership Dues
(please remit in U.S. funds):

	U.S.	Outside U.S.
Individuals, amateur clubs, school or public libraries:		
Mercury only	$ 29.50	$ 37.50
Mercury & Publications	$ 65	$ 75
Institutional subscriptions:		
Mercury & Publications	$ 159	$ 169
Graduate Student (thesis advisor must sign application and renewals)	$ 30	$ 40

For more information about membership (including graduate student membership), back issues, advertising, donations, bequests, and the Society's educational programs, please write to:

Information Department
Astronomical Society of the Pacific
390 Ashton Ave.
San Francisco, CA 94112. Or call: (415) 337-1100

This issue of *Mercury* was composed and typeset with Macintosh computer equipment generously granted to the A.S.P. by Apple Corporation.