Payne-Gaposchkin, Cecilia Helena | Encyclopedia.com

(*b*. Wendover, Buckinghamshire, United Kingdom, 10 May 1900; *d*. Cambridge, Massachusetts, 7 December 1979), *astrophysics*.

Payne was born to a family with genealogical and intellectual connections to the intelligentsia of England. A box of letters she had inherited from her family included the autographs of Charles Darwin and the geologist Charles Lyell. Her father, Edward Payne, a lawyer, musician, and scholar, died when she was four, so she was essentially raised by her mother, Emma Pertz Payne. Her educational trajectory took her in 1919 to Newnham College in the English Cambridge, where she was allowed the unusual combination of botany, physics, and chemistry. Though she was soon disillusioned by botany, her love of taxonomy found a natural niche in her ultimate pursuit of astronomy, where she eventually became a relentless classifier of variable stars, although her reputation as the most eminent woman astrophysicist of all time began with her doctoral dissertation on stellar spectra.

In Cambridge her interests turned more strongly to physics and then, inspired by a lecture on relativity by Arthur Eddington, to astronomy. In May 1922 Harlow Shapley, the newly appointed director of Harvard College Observatory, visited England and spoke at the Royal Astronomical Society. Payne, in the audience, was captivated, and after the lecture expressed to him her desire to study astronomy at Harvard. Shapley encouraged her dream and, after receiving recommendations that praised her energy, enthusiasm, and originality, arranged for a fellowship at Harvard.

Her contemporaries at Harvard would later describe her as an extraordinary figure and a stormy personality. Payne arrived in America in September 1923, for what was to become her lifelong home; she knew that in England astronomical research opportunities for women were extremely limited (and, for example, women were not ordinarily made members of the Royal Astronomical Society). Though she found the atmosphere in the American Cambridge "intoxicating," she later described New England as a "stony-hearted stepmother," a literary allusion from Thomas De Quincey's *Confessions of an English Opium Eater* typical of her humanistic erudition (Haramundanis, p. 129). By June 1924 she had already taken a preliminary general examination for a PhD (arranged by Shapley and Theodore Lyman, chairman of the Harvard Physics Department) and the academic year 1924–1925 was spent researching and writing her doctoral thesis.

Although Shapley had originally suggested that she should take up a topic in stellar photometry, her undergraduate background in England with luminaries such as Eddington and Ernest Rutherford led her inexorably toward astrophysics, and in particular to the great collection of photographic stellar spectra in the plate stacks at Harvard Observatory. Throughout the nineteenth century, the temperatures of stars were seen as a central unsolved astrophysical problem. By the early 1920s, especially following the pioneering work of Meghnad Saha in 1920–1921, the first tables that correlated spectral type with surface temperature were published. There was much disparity between them, and when Payne began to work on this problem, it was indeed a hot problem in astrophysics.

Her solution was so ingenious and satisfactory that it essentially turned the temperature scale into a nonproblem, with the result that astronomers have tended to forget the significance of this achievement and its consequences. What she did was to use the new quantum mechanical understanding of atomic structure, that is, the energy levels and how they are populated, to examine the temperature where a given atomic level would reach its maximum population. Employing these concepts not only for hydrogen but for the other major elements with conspicuous lines in the visible region of the stellar spectra, she established that despite the varied appearance of these spectra, their differences resulted essentially from the physical conditions and not from Abūndance variations. This chemical homogeneity of the starry universe was the essential point of her thesis, and it is this result that Otto Struve highlighted when he called her book, *Stellar Atmospheres*, "undoubtedly the most brilliant PhD thesis ever written in astronomy" (Struve and Zebergs, 1962, p. 220). It was a stunning insight into the uniformity of nature in the chemical construction of the universe.

But there was more. Following Part II, called "Theory of Thermal Ionization," comes Part III, "Additional Deductions from Ionization Theory," and in a short chapter titled "The Relative Abūndance of the Elements" there

is a ticking time bomb. This finding was the extremely high Abūndance of hydrogen and helium that had emerged under certain assumptions in the analysis. To the astronomers of the day, such a result was as ludicrous as the heliocentric cosmology had seemed to Nicolas Copernicus's contemporaries. All the experts believed that iron had to be the most Abūndant element. The density of Earth could be understood only if our planet had a heavy iron core. Meteorites from outer space confirmed that iron was widely Abūndant. And the Sun's spectrum showed vastly more iron lines than any other element. When Eddington demonstrated that stars were gaseous throughout and that they shone because of an energy source concentrated in their hellishly hot cores, he did so assuming that the Sun was made of iron.

Unexpectedly, Payne's calculations, made with meticulous thoroughness, showed something different. They indicated that hydrogen (as well as helium, which ran a distant second) were overwhelmingly Abūndant compared to iron, which seemed a mere whiff in the cosmic composition. However, even Payne was persuaded (largely by Shapley's mentor, Princeton astrophysicist Henry Norris Russell), incorrectly as it turned out, that something was amiss in the physics of these two lightest elements. Nevertheless, before the decade was out, other observations convinced astronomers (led by Russell) that Earth was not, after all, typical of the cosmos as a whole, and that iron seemed only a minor contaminant in the larger world of stars and galaxies. Payne was delighted when Eddington, in his magisterial book *The Internal Constitution of the Stars* (1926), included a sentence to say that her original deductions were "not so wild as we might suppose," but she had forfeited the opportunity to be the one who convinced astronomers that hydrogen was so Abūndant in the universe (p. 369).

By the time Payne had completed her doctorate she had already finished a total of six papers. Her thesis clearly played a seminal role in the development of astrophysics. In 1926 she became the youngest astronomer ever starred in *American Men of Science*, and two years later she became a member of the International Astronomical Union and was appointed to the Commission on Spectral Classification. The astrophysicist Jesse Greenstein, who first met her when he was a Harvard undergraduate in 1927, recalled that, "it was not uncommon to find her personally upset or tense, but willing to talk for hours about literature, or science.… Her intuition as to what was important in astronomy was truly deep" (Haramundanis, 1984, p. 8).

Payne subsequently researched the intrinsically brightest stars, and first described many of their peculiarities and identified numerous exotic ions in their spectra. Her second Harvard College Observatory monograph, *The Stars of High Luminosity*, appeared in 1930, followed by additional papers on these rare and unusual stars. Her studies provided the foundation for later work in which she used these brilliant beacons to probe the distant structure of our Milky Way system. Between 1923 and 1942, she was author or coauthor of seventy-eight papers dealing with the analysis of stellar spectra.

But it was a man's world and when Shapley began to assemble teachers for an astronomy graduate department at Harvard, he looked elsewhere. Thus the astrophysics appointment went to the Canadian astronomer Harry Plaskett, and when he left for Oxford, the position fell to Donald Menzel, a doctoral student of Russell's who had originally come to exploit Harvard's collection of spectra at the same time as Payne (thereby creating for Shapley an awkward duplication of competing interests). As a consequence of these appointments, Payne was shunted aside from her beloved spectra and astrophysics, and to maintain a research position, she was obliged to work on stellar photometry, which she did with more competence than enthusiasm. When in 1934 Princeton's president inquired with Henry Norris Russell about a possible staff member to groom as his replacement, Russell wrote that the best candidate in America "alas, is a woman!—not at present on our staff," an obvious reference to Payne (DeVorkin, 2000, p. 341).

In 1933 Payne toured the observatories of northern Europe, going as far as Leningrad. At the Astronomisches Gesellschaft meeting in Göttingen she met a young Russian-born astronomer, Sergei I. Gaposchkin, who was trying to escape Nazi persecution. Back in the United States, she went to Washington, D.C., to expedite a visa for this stateless man, she persuaded Shapley to offer him a position at Harvard Observatory, and in March 1934 she became Cecilia Payne-Gaposchkin. Theirs was a tempestuous but enduring relationship; the couple became the parents of a daughter and two sons, all of whom have scientific careers.

From 1928 through 1942 Payne-Gaposchkin was author or coauthor of fifty-eight papers dealing with photometry. But, she later reported in her autobiography, her efforts to establish standards photographically for red and yellow magnitudes "was labor thrown away" (Haramundanis, 1984, p. 184); photoelectric standards were coming, and the day of absolute photographic photometry was over. However, building on her researches on stellar photometry, the Gaposchkins began an ambitious systematic investigation of all known variable stars brighter than the tenth magnitude. "The time was ripe for such a survey," she later wrote. "Twenty years earlier the data would have been too sparse… Thirty years later, they would be unmanageable" (p. 199). Her astonishing encyclopedic memory made these stars her personal friends and provided a constant source of amazement to her colleagues. The Gaposchkins' 1938 monograph *Variable Stars* quickly became the standard reference. Subsequently, during the late 1930s and 1940s, with the help over time of twenty-nine assistants, they made more than 1,250,000 measurements of variable stars on the Harvard photographic plates.

In 1939 they were invited to a select international conference in Paris on novae and white dwarf stars, indicative of their stature in the variable star field. The meeting took place on the very brink of World War II. When the United States entered the war, the Gaposchkins purchased and equipped a poultry farm in central Massachusetts, from which they sent thousands of eggs and hundreds of turkeys to the market, but their intentions to provide employment for a refugee family went unfulfilled. They also organized a Forum for International Problems, which met at the observatory and which attempted to represent each side of the issues, but which earned for Payne-Gaposchkin the reputation of being a dangerous radical.

Early in her career Payne wrote that "observations must make the way for theory," (Payne-Gaposchkin, 1925, p. 200) and from her storehouse of information she put together empirical patterns that helped define the structure of our galaxy and the paths of stellar evolution. Her boldly titled popular book of 1952, *Stars in the Making*, came when most astronomers assumed that the age of the Sun was essentially the age of the universe, and when they were only just starting to appreciate the vast quantities of hydrogen in interstellar space. There she wrote, "We can even toy with the idea that stars are being born continuously, and the places where the young stars are found suggest very definitely that they are born in the interstellar dust" (p. 118), ideas that soon became commonplace. Her monographs *Variable Stars and Galactic Structure* (1954) and *The Galactic Novae* (1957), and her final book *Stars and Clusters* (1979), published shortly before her death, helped link more closely the connection of star births with the structure of the Milky Way. However, her patient posthumous editing of Walter Baade's 1958 Harvard lectures, *Evolution of Stars and Galaxies*(1963), may have been her most influential contribution toward the general understanding of the evolutionary significance of the population of hot, young supergiants and Cepheid variables in the spiral arms of galaxies, in contrast to the population of older stars and the RR Lyrae variables in the globular clusters and galactic nuclei.

Much as Payne-Gaposchkin might have wished to obtain her own observations, particularly high-dispersion spectra of stars, to fuel her astrophysical interests, she was in a singularly poor position to procure these. Harvard Observatory at that time did not have adequate spectrographic facilities for herself or her students. The large telescopes in the American West were entirely male dominated during those years, and at best she could beg spectra of secondary interest from her western colleagues.

But she continued to make use of the plates acquired by Harvard, particularly from the southern stations. In the 1960s the Gaposchkins undertook a systematic reanalysis of the variable stars in the Magellanic Clouds, based on the photographic plates in the Harvard collection. Sergei Gaposchkin and eighteen assistants made more than a million visual estimates of magnitudes for variable stars in the Magellanic Clouds and Payne-Gaposchkin derived the periods for 3,100 of them. Later (in 1974) she noted that the Cepheid variables with the longest periods (and therefore the youngest stars) were concentrated at the northern end of the Large Magellanic Cloud's well-known and conspicuous bar. She outlined the broad history of the relatively recent burst of star formation in this nearby galaxy, which about 100 million years ago swept from the southeast to the northwest ends of the bar, with a duration of about 20 million years.

In 1936 Payne-Gaposchkin became a member of the American Philosophical Society (America's oldest scientific academy), and shortly thereafter of the American Academy of Arts and Sciences, but academic advancement at Harvard was long denied to women. Though she lectured at the observatory and advised doctoral dissertations, her classes were not listed in the course catalog until 1945. In 1956 she became the first woman professor to have received tenure at Harvard, although she was not the first tenured woman professor at Harvard. The basis of this curious distinction is that she was tenured by the Harvard Corporation in 1938 as Phillips Astronomer, but she did not become a professor until 1956, by which time three other women had become professors in the arts and sciences. When Payne-Gaposchkin became Phillips Professor, she was simultaneously appointed department chairman, the first woman to achieve this distinction at Harvard. At a party celebrating her appointment, she described herself as "cast in the unlikely role of a thin wedge" (Haramundanis, 1984, p. 29), which brought down the house because she was, in fact, of imposing stature. In 1977 she received the highest honor of the American Astronomical Society, the Henry Norris Russell lectureship.

At the end of her life Payne-Gaposchkin wrote her autobiography, taking her title, *The Dyer's Hand*, from William Shakespeare's "Sonnet 111":

And almost thence my nature is subdued To what it works in, like the dyer's hand

but never mentioning the source. Well-versed in classics both early and modern, as well as music and art, it may never have occurred to her that many readers would not recognize the context of the title or of dozens of other literary allusions that peppered her text. Long a dedicated chain smoker for whom a single match sufficed for an entire class lecture, she eventually succumbed to cancer a few months before her eightieth birthday.

BIBLIOGRAPHY

Payne-Gaposchkin never systematically retained her correspondence, so her papers in the Harvard University Archives are sparse. Some early letters are found among Harlow Shapley's Director's files there, and a few others are in the Margaret Harwood archives in the Schlesinger Library of the Radcliffe Institute in Cambridge, Massachusetts. There is an oral history interview by Owen Gingerich in the American Institute of Physics, Niels Bohr Library.

WORKS BY PAYNE-GAPOSCHKIN

Stellar Atmospheres: A Contribution to the Observational Study of High Temperature in the Reversing Layers of Stars. Harvard Observatory Monographs, no. 1. Cambridge, MA: Observatory, 1925. Her dissertation.

The Stars of High Luminosity. Harvard Observatory Monographs, no. 3. New York: McGraw-Hill, 1930.

With Sergei Gaposchkin. *Variable Stars*. Cambridge, MA:Observatory, 1938.

Stars in the Making. Cambridge, MA: Harvard University Press,1952.

Variable Stars and Galactic Structure. London: University of London, Athlone Press, 1954.

The Galactic Novae. Amsterdam: North-Holland; New York:Interscience Publishers, 1957.

As editor. *Evolution of Stars and Galaxies*, by Walter Baade.Cambridge, MA: Harvard University Press, 1963.

Distribution and Ages of Magellanic Cepheids. Washington, DC:Smithsonian Institution Press, 1974.

Stars and Clusters. Cambridge, MA: Harvard University Press,1979.

Cecilia Payne-Gaposchkin: An Autobiography and Other Recollections. Edited by Katherine Haramundanis. 2nd ed. Cambridge, U.K.: Cambridge University Press, 1984. Note especially "An Introduction to 'The Dyer's Hand'" by Jesse Greenstein, "An Historical Introduction to 'The Dyer's Hand'" by Peggy A. Kidwell, and "A Personal Recollection" by her daughter, Katherine Haramundanis.

OTHER SOURCES

DeVorkin, David. *Henry Norris Russell, Dean of American Astronomers*. Princeton, NJ: Princeton University Press, 2000.

Eddington, Arthur Stanley. *The Internal Constitution of the Stars*.Cambridge, U.K.: Cambridge University Press, 1926.

Gingerich, Owen. "Cecilia Payne-Gaposchkin." *Quarterly Journal of the Royal Astronomical Society* 23 (1982): 450–451.

Philip, A. G. Davis, and Rebecca A. Koopmann, eds. *The Starry Universe: The Cecilia Payne-Gaposchkin Centenary; Proceedings of a Symposium Held at the Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts, October 26–27, 2000*. Schenectady, NY: L. Davis Press, 2001. Note especially "'The Most Brilliant Ph.D. Thesis Ever Written in Astronomy'" by Owen Gingerich, and "Cecilia and Her World" (including an extensive photographic section) by Katherine Haramundanis.

Struve, Otto, and Velta Zebergs. *Astronomy of the 20th Century*.New York: Macmillan, 1962.

Owen Gingerich