100 years ago

A. Schnell

Institute for Astronomy, University of Vienna, Türkenschanzstr. 17, A-1180 Vienna, Austria

Abstract. In 1897 Antonia Maury discovered chemically peculiar stars; for the first time 100 years ago female students got permission to study at the University of Vienna. In commemoration of these events, some details about education and training and about the careers of women at the turn of the century are presented.

Key words: History – Equal opportunity

In 1897, a detailed study of spectra of 681 bright stars was published by Antonia Maury under the direction of Edward C. Pickering, in Volume 28 of the Annals of the Astronomical Observatory of the Harvard College, as part of the Henry Draper Memorial. From the preface we learn that this work was assigned to Miss Maury in 1888 and that she alone was responsible for the classification. In the remarks to the spectrum of α^2 Can Ven, she uses for the first time the designation *peculiar* for the description of special features. Altogether she mentioned 9 stars with a peculiar spectrum and thus defined for the first time a group of chemically peculiar stars – so we may celebrate the 100$^{\text{th}}$ anniversary of the discovery of those objects by one of the pioneer ladies of spectral classification.

In 1897, by a decree of the emperor, women were accepted at the University of Vienna for the first time to study at the faculty of philosophy; and in the same year, a woman was first to graduate in medicine with the M.D. – another anniversary we may commemorate.

So I want not only to report about the achievements of women in astronomy in the United States at the end of the last century, but also to compare them with the situation of women in Middle Europe at the same period.

Besides ability, the most important requirement for any person to work in a scientific field is education and training. Until the end of the 18$^{\text{th}}$ century all children were educated and taught at home. With the founding of the school and university system, which was a non-coeducational one, girls were excluded. So only the establishment of high schools, colleges and universities for women, as it happened in the United States, or the permission for women to attend boys schools and universities, ended the limitation of access to higher education for them. While in the United States high schools for women were opened early in the 19$^{\text{th}}$ century and colleges later on, girls in Europe were usually not admitted to high schools. They could only be nonregular pupils. In Austria, for example, girls could attend some schools, but they could not graduate and they were not considered "mature" enough to continue studies at the universities. The first

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high schools for girls were founded in 1890. Earlier attempts had been refused with reference to the “lower weight of the female brain”. In 1897, nearly at the time of the opening of the university to women, a proper graduation at a girls high school in Vienna was possible. In the following semester, only three women made use of their new right or, one can also say, got permission from the dean of the faculty, because he had the right to accept or refuse a female student. For a long time, the admission of women was more or less exceptional rather than standard. Their presence at the universities was symbolic, if not practically non-existent.

The first European university with matriculation for women was that of Zurich from 1840 onwards, but not for Swiss residents, only for foreigners. Women from the entire Austrian monarchy studied and graduated there with the M.D. (Felkl, 1997).

Table 1. Admission of women to universities – the international situation.

Year	Country (Region)
1833	USA
1840	Switzerland
1863	France (no theology)
1869	Great Britain
1872	Russia (only medicine)
1870 – 1894	Italy, Sweden, Finland, Denmark, Norway Belgium, Turkey, Greece, Netherlands
1897	Austria
1900	Heidelberg (Baden)
1901	Russia
1908	Prussia

One of these women was Gabriele Possaner von Ehrenthal, born in 1860 in Budapest. Her father was a civil servant of high rank in the Viennese Finance Ministry. She came – as did all other women fighting for a good education at that time – from a well-situated background. In middle class families it became clear for the first time that the traditional lifelong support of women through marriage was no longer guaranteed. The initial training Gabriele Possaner got was that of a teacher – a profession already accessible to women. In 1887 she was the second woman to graduate at the Vienna Academic Gymnasium, a well known high school. Since she wanted to be a medical doctor, she moved to Switzerland. There Austrian high school graduation did not mean admission to university, so she again passed all the exams of high school graduation with great success and studied at the universities of Geneva and Zurich. In 1894 she graduated and returned to Vienna. Since she really wanted to work as a doctor, her degree had to be acknowledged in Austria. This process lasted for three years: one Emperor, two Home Secretaries, three Secretaries of Culture and Education, four Rectors of the University of Vienna and four Deans of the Faculty of Medicine were involved. In 1896 it was decided, that she had to repeat all principal exams in Vienna. Within nine months she took twenty-one examinations and received her graduation. Soon afterwards she started her own surgery and became a member of the so called "Ärztekammer", the professional organisation of medical doctors. Her attitude was of significant benefit to women.

Table 2. Studies of women in Austria - a chronology

1878 05 06	"Sitting in" at university courses for women permitted in exceptional cases
1895 11 18	Admission of women to study philosophy, medicine and pharmacy in the Hungarian part of the Monarchy
1896 03 09	Highschool graduation for women without the permission to study at universities
1897 03 23	Admission of women to the philosophical faculties of the universities
1897 04 02	First Graduation of a woman: Gabriele Possaner von Ehrenthal as M.D.
1900 09 03	Admission to pharmacy and medicine
1919 01 21	University of Veterinary Medicine
1919 May	Technical University and University for Agricultural Sciences
1919 06 12	Law
1920/21	Academy of Fine Arts
1922	Protestant Theology
1932	Roman Catholic Theology without graduation, withdrawn by the "Bischofskonferenz" (episcopal conference) in 1936, again permitted in 1938
1945	Roman Catholic Theology with graduation

The fourth woman to graduate at the University of Vienna was Lise Meitner. She was born in 1878 and her father was a Jewish lawyer in Vienna. Already during high school time – she also visited the Academic Gymnasium – she was attracted to the studies of mathematics and physics. Her father anticipated lots of potential difficulties and suggested a training as a teacher of French. In his opinion this would offer a good chance for employment, even for someone with a Jewish background. She passed all the necessary exams and worked as a teacher for one year. Influenced by newspaper reports about the work of Marie and Pierre Curie she never gave up the idea of studying physics. She prepared for a special high school graduation with a private teacher and in 1901 was the first woman at the University of Vienna to attend a class in physics. She studied mostly with Ludwig Boltzmann and received her Ph.D. in 1906. She wanted to work with Max Planck – she had met him in Vienna during one of his visits – and in 1907 she moved to Berlin, living there with the financial support of her father (Bührke, 1997).

In 1907 in Berlin – four years after Marie Curie, together with her husband and Henry Becquerel, had received the Nobel Prize, and one year before Marie Curie was to become the first woman professor at a French university – women still were not permitted to study at this university. They might be allowed to audit courses if they could find an indulgent lecturer. When Lise Meitner came to Berlin, Max Planck said: You already got your Ph.D., what more do you want? (*"Aber Sie sind doch schon Doktor. Was wollen Sie denn noch?"*). As we know today, Planck had an ambivalent relation to women in science, he was not principally against them; but he preferred them as exceptions to the rule (Vogt, 1997). He supported extraordinary good female students at a time when e. g. women were not allowed to enter the institute for chemistry. After Lise Meitner had met Otto Hahn and started her cooperation with him, she could not set foot in the institute where he worked. The director, Emil Fischer, did not permit it because of the lack of a ladies' toilet. They had their first lab in an old workshop. At least the people at the institute for physics soon accepted her, and in 1912 Planck offered her a position as an assistant. She qualified for inauguration and became recognized as academic lecturer in 1922 at the age of 44. In 1926 she was named extraordinary professor, a title she held until deprived of it by Hitler's decrees in 1933. She rose to the rank of head of her own section of the Kaiser-Wilhelm-Institute and was a leading participant in the newly fledged discipline of nuclear physics. Lise Meitner was always more concerned with her work than anything else and had a complete lack of interest in politics. Protected by her friends she stayed in Berlin until July 1938 – until it was almost too late to flee. In Sweden she continued to cooperate with Hahn and Straßmann as long as possible and played a vital role in their discovery of fission. She should have shared the Nobel Prize Hahn received in 1944. Some of the recognitions and honours she received were the Leibniz Medal of the Berlin Academy of Science in 1924, and the Ignaz-L.-Lieben Prize of the Vienna Academy. In 1948 she became the first female member of the Austrian Academy of Sciences.

These two examples show the lives of two pioneer ladies of science in Austria and in Europe. Their way was paved with obstacles and difficulties and despite all the problems at the beginning of their career they met with approval and appreciation at least in some way. They showed that the old German saying that women have to be devoted to *Kinder, Küche and Kirche* (children, kitchen and church) had not to be a rule. But usually the increasing importance of science in society and all improvements in educational opportunities for women did not imply the availability of jobs identical to those held by men.

In the United States, at the end of the last century, the availability of education for women was much better because it had existed already for a long time. The spread of a public school-system originated from the conviction that democracy requires a literate electorate, even at a time when the right to vote was limited to men. As soon as schools spread, girls demanded admission too. The next step forward occurred when women began to teach. It was soon discovered that they were not only competent but could be hired at half the salary paid to a man. By the middle of the 19^{th} century, normal schools were established for teacher training. These carried education beyond the high school level and were open to women. The Civil War brought new opportunities: the sharp decline in the school enrollment of men forced some institutions to accept women. By 1870 two thirds of the teachers in public schools were women; more than half of the high school graduates were girls; and one college student out of nine was a woman. It soon became evident, that women preferred coeducational schools. This was partly due to the fact, that private colleges were expensive, and partly because public rather than private institutions prepared students specifically for teaching and other professions that appealed to women. In 1890 the expenses per year a family had to pay for a daughter studying at Wellesley were $ 350; only people from the expanding middle class could afford this amount – the average income of a medical doctor amounted to $ 1 200. The opportunities for an academic career were rare and existed at women colleges only: women became primarily teachers and served as inexpensive labourers.

Table 3. Women's Colleges in United States

Year	Number of colleges founded	Examples
1772	1	Moravian
1780–1800	0	
1800–1810	1	
1810–1820	1	
1820–1830	1	
1830–1840	5	Mount Holyoke
1840–1850	13	
1850–1860	12	
1860–1870	6	Vassar
1870–1880	11	Smith, Radcliffe, Bryn Mawr Wellesley
1880–1890	18	Barnard
1890–1900	10	

At some high schools and even at colleges, astronomy courses were given, which female students could attend. According to a study by Hoffleit (1994), by 1890 there were over 2 500 high schools, 16 of which offered astronomy; of these, 10 were open to girls. By 1900, 79 girls colleges had been founded; together with the coeducational colleges or universities, nearly 100 institutions offered higher learning to women high school graduates. At relatively few of those, however, astronomy was taught. Furthermore we have to keep in mind, that the colleges offered undergraduate education. Graduate education was available only at universities which were restricted to male students. The first woman Astronomy Professor in America was Maria Mitchell, appointed in 1865 by Matthew Vassar at the liberal arts college for females which included an observatory with a 12 inch telescope, at that time the third largest in the United States. She received a salary of $ 800 compared to $ 2500 paid to male professors.

Maria Mitchell was born in 1818 to a Quaker family on the island of Nantucket. Her father, a friend of the Bonds, the first two directors of Harvard Observatory, was interested in astronomy and owned a telescope. For example he was one of the first in America to rediscover Halley's Comet in 1835 before it was visible without the aid of a telescope. The Quakers, already in the early 19^{th} century, felt strongly that girls should receive an education equal to that of boys. So Maria Mitchell was not only raised in an intelligent home, where she was introduced to astronomy, but also was taught in the school her father ran. Later on she attended one of the first normal schools for the training of teachers for girls only in Lexington, impressing her teachers especially by her abilities in mathematics. In 1835 by newspaper advertisement she started her own public school for the "rich or poor and black or white". She had to close the school one year later because it was not making enough money. Fortunately she was appointed as librarian in the Athenaeum, Nantuckets public library, a post she held for about twenty years. This position offered the luxury of time to work in astronomy, because the library was only open in the afternoon and on Saturday evening.

In 1847 she discovered a faint comet, for which she was awarded a gold medal offered by the king of Denmark for such discoveries. That made her famous: in 1848 the American Academy of Arts and Sciences elected her as its first woman member. The Association for the Advancement of Science did the same in 1850. In 1849 she was offered a job and employed by the U.S. Nautical Almanac Office as a computer of tables of positions of Venus; she continued this occupation for 19 years.

She also started travelling to attend scientific meetings. In 1857/58 she went to Europe (partly accompanying a young lady from a rich family), met Caroline Herschel, visited Greenwich Observatory and met Mary Fairfax Somerville in Italy. She had hoped to visit the Vatican Observatory as well, where women were not admitted. She finally succeeded in getting special permission – but only in the daytime.

After returning home, she got a new telescope as a present bought with money collected by women for the first woman astronomer of the United States. This telescope still is in the Maria Mitchell Observatory in Nantucket, run by the Nantucket Maria Mitchell Association as a memorial to her.

In Vassar she dedicated her time to teaching rather than to research, well aware of the fact that training and education were most important to her students. She encouraged her students who were her daily companions, and motivated them to work meticulously.

Over the course of her life she became more and more interested in the cause of women's rights in general and in women's science education in particular. In 1873 she was one of the founders of the American Association for the Advancement of Women (working for the idea of giving women the right to vote and to own property). She received three honorary degrees and was elected president of the Philadelphia Meeting of Women's Congress in 1876. Because of poor health she retired at Vassar in 1888 and died in 1889. In 1905 she was elected to the Hall of Fame of Great Americans (Dobson & Bracher, 1992; Hoffleit, 1994; McKenney, 1904).

Among Maria Mitchell's students was Antonia Maury who received the B.A. at Vassar in 1887 and was employed at Harvard from 1888 intermittently through 1933. Women were first hired at Harvard College Observatory in 1875; the administration was probably aware of the fact, that the Coast Survey or Nautical Almanac Office had employed Maria Mitchell. They were employed as assistants, usually called "computers". A significant phase of their education was on-the-job training or learning by doing. The women were paid 25 to 35 cents an hour of work six days a week, seven hours a day. This salary was below what a woman could earn with clerical work at that time and above that of an average factory worker. Payment for women at Harvard remained at that level at least until 1906 and it was rather meager, taking into acount that most of these women had college education. Among these women in the early times were Anna Winlock (1875) and Selina Bond (1879), both daughters of observatory directors. They were interested in astronomy but they also had to work because they were in pecuniary need and had to help support their families after their father's death.

In a letter to an applying woman, Arthur Searle defined the abilities required as: *"A knowledge of ordinary arithmetic and a legible handwriting are all the necessary qualifications of a computer, although of course, the more that is known of languages and mathematics the better."* (Mack, 1990). Needless to say, better knowledge of anything did not mean a better position. It was believed that the intellectual abilities of women suited them for that kind of repetitive, non-creative data gathering projects; the jobs required docility, submission and painstaking work. As anywhere else those jobs were *"so low paying or low ranking that competent men would not take them"* as Margaret Rossiter (1982) notes. On the other hand, these women got on with the job in a wonderful way, performed well, complied with the needs and helped an observatory's director save money and keep within a given budget. Records show that 164 women worked for various observatories in the United States between 1875 and 1920 (Wolfschmidt, 1995).

In 1877 Edward Charles Pickering became director of Harvard Observatory. He is the best example of being supportive of women working in astronomy but his motivations also had economic reasons. In the time of his directorship 44 women, more than in any other observatory, were employed. The amount of applications for such jobs exceeded the number of people he had money to hire.

Pickering's concept of science was the strong belief that the largest contribution can be done by collecting large amounts of data. The German word "Durchmusterung" partly fits that concept. He stated some concepts of his directorship (Plotkin, 1990): *" A second principle maintained has been the special advancement of the physical side of astronomy. ... the policy has been rather to undertake such studies of the physical properties of the stars as would not be likely to be made at other observatories ..." " ... thirdly the undertaking of large pieces of routine work and the employment of numbers of inexpensive* *assistants whose work is in a great measure mechanical, such as copying and routine computing ... In each important investigation ... this involves a repetition of the work many hundreds, or even thousands of times, and renders it necessary that the observers and computers shall continue for years upon work of the same character".*

First he started the Harvard photometry, a determination of stellar magnitudes on a uniform scale. Just at that time new technologies such as photography became available and Pickering started with photographic photometry and wanted to chart all visible stars by means of photography. Soon he also got interested in spectroscopy. The main task of people working in those fields was no longer doing observations at a telescope, much more work had to be done in laboratories inspecting and measuring plates and reducing data. This was typical women's work or as H.S. Davis stated in 1898 in an article about contemporary women astronomers *" has wonderfully increased the opportunities for women in pursuit of the truths of nature".*

Thanks to the generosity of Mrs. Henry Draper, widow of a pioneer in astrophysics and as a memorial to her late husband (Henry Draper (1837–1882) who had made the first photograph of a stellar spectrum – Vega – using his homemade telescope) and as a result of Pickering's outstanding ability to secure money for the Harvard Observatory, a fund was established at the observatory to photograph, measure and classify the spectra of all the stars visible from Cambridge. Pickering was able to convince Mrs. Draper to establish that fund: between 1886 and her death in 1914 she donated more than \$ 237 000 and left an additional amount of \$ 150 000 to the observatory through her will. With that money he hired the female assistants nowadays well known as "Pickering's Harem".

From a statement given by Pickering in the Annual Report of 1898 we may conclude that primarily economic reasons played an important role in his decision to employ assistants, but one also has to be aware of the fact that this special kind of work organisation at Harvard College Observatory secured the power and authority of the director: *The Director of the Harvard College Observatory takes immediate charge of the various departments, in many cases making a daily inspection and planning the work in detail. Many of the assistants are skillful only in their own particular work, but are nevertheless capable of doing as much and as good routine work as astronomers who would receive much larger salaries. Three or four times as many assistants can thus be employed, and the work done correspondingly increased for a given expenditure. This method does not offer the same opportunity for the advancement of individuals, and too much depends upon a single person – the director* (Pickering, 1898).

All Harvard assistants, male and female, performed routine work, but the contributions of four Harvard women are of outstanding importance for astronomy. Williamina Fleming, Antonia Maury, Annie Cannon and Henrietta Leavitt used the chances given to them, however in different ways. They developed strategies for expanding on the available opportunities, but were limited by Pickering when they wanted to do more than accumulate data.

Williamina Paton Fleming, born in 1857 at Dundee, Scotland, attended a public school in Dundee, and at the age of 14 she became a pupil-teacher. In 1877 she got married and emigrated with her husband to Boston in 1878. One year later she was abandoned by her husband while pregnant with their child. In order to support herself and the baby – nowadays we would call her a single mother – she obtained work as a maid in Edward Pickering's home. It is reported (Hoffleit, 1994) that Prof. Pickering was not content with the work performed by one of the men employed, got very angry and declared that his maid could do a better job than he did. He hired her in 1881 to do clerical work and some mathematical calculations. *Her duties were at first at the simplest character, copying and ordinary computing* (Turner, 1912). Her knowledge and efficiency developed with work, her duties were expanded until she occupied one of the most important positions at the observatory, and in 1899 she was appointed curator of astronomical photographs. First she helped establish the Pickering-Fleming System in which objective prism spectra are arranged in order of increasing complexity. She was put in charge of the original examination of the photographic plates, their care and storage, and the classification of objects as well. Soon she became supervisor of the increasing number of women assistants. Miss Cannon (1911) describes her as *gifted with great keenness of vision and a clear and logical mind* and says, that *her industry was combined with great courage and independence*. She edited all the publications issued by the observatory, which means that she also had to do the final proof reading. Credit is given to her work by Pickering from 1890 onwards: her name is mentioned in every Annual Report of the Director of the Astronomical Observatory of Harvard College.

In two volumes of the Draper Memorial, a catalogue of the photographic spectra of 10 351 stars north of -25^o was published. Furthermore, she selected and measured the positions of a sequence of comparison stars for 222 variable stars discovered by her. In total, she found more than 300 variable stars, she discovered by the presence of bright lines in their spectra 10 novae and 94 Wolf-Rayet stars. Most of her results were published by Pickering in the Harvard Annals and the Harvard Circulars; in 1895 she published two papers in the Astrophysical Journal and the Astronomische Nachrichten under her own name; they were followed by one paper in the Astrophysical Journal in 1896.

As a mother she must have done extremely well – her son graduated as mining engineer from MIT in 1901 and worked for a large copper company in Chile. Miss Cannon (1911) writes in an obituary that *the long years of observatory work never unfitted her for the domestic side of life. She was as much at home with the needle as with the magnifying eyepiece*. Turner (1912) states that *it would be unjust not to remember that she left her heavy daily labour at the observatory to undertake on her return home those household cares of which a man usually expects to be relieved*. Statements or evaluations like that are extremely unusual; they show that she behaved well and was content with the role assigned to her by the common idea of women's place in astronomy.

Because women were not allowed as regular members, she was made an honorary member by the Royal Astronomical Society in 1906; soon after she was appointed the only honorary fellow in astronomy of Wellesley College. She was an active member of the Astronomical and Astrophysical Society of America and of the Société Astronomique de France. In 1910 she received a gold medal of the Sociedad Astronómica de México, to which she was elected as honorary member in 1906. At the 1893 Chicago World Fair she gave a talk on "A Field for Women's Work in Astronomy". She died in 1911 at the age of 54.

In the Annual Report for 1911 Pickering (1912) calls her death *a severe loss* for HCO. *Mrs. Fleming's record as a discoverer ... was unequalled. Her gifts as an administrative officer, especially in the preparation of the Annals, although seriously interfering with her scientific work, were of the greatest value to the Observatory.*

Quite the contrary of a person obeying rules and behaving well was Antonia Maury. She was born in 1866 and got a good education at Vassar College, graduating with the B.A. in 1887. She was the niece of Henry Draper and the granddaughter of John William Draper, the American pioneer in the application of photography to astronomy. I would judge from that background that she came from a well situated family and her wish to get a job was not of pecuniary need. But at the time of the establishment of the Henry Draper Memorial at Harvard she wanted to participate in that programme; therefore her father, a minister and naturalist, asked Pickering to give her a job. She started to work in 1888 and was assigned to do a detailed study of spectra made with prisms in front of the telescope of bright northern stars. She was not content with the Pickering-Fleming system already established at Harvard and tried to develop a more complex system of her own. Contrary to the other computers she was creative and not perceptive. She examined the arrangements of the spectral lines, their width and their sharpness and set up a scheme of 22 Roman numbered types subscripted with three sharpness classes. She also found that in the sequence of the Pickering-Fleming system, class B should precede class A. This classification scheme was inadequate for routine work; it required more time and was not easy to use. Pickering was in favour of his more efficient system and wanted her to do her job in the way he expected her to do it. She had two possibilities: either finish the work or turn it over to someone else (Mack, 1990). Since she disagreed with Pickering, Maury decided in 1892 to leave the observatory, and after 1896 she worked mostly as a volunteer.

There is one battle she won: after completion of her catalogue for publication she fought for more than the standard acknowledgement (Mack, 1990). Volume 28 of the Harvard Annals was the first with a woman's name on the title page; even Fleming in the first Draper Catalogue was rewarded only by an acknowledgement. So at least she received some appreciation, but her classification system was no longer used in Harvard. Even Hertzsprung failed in convincing Pickering of the value of Maury's work, which had led to the distinction between giant and dwarf stars, the c-characteristic corresponding to the high luminosity group. Hertzsprung wrote to Pickering in 1908: *But in one respect I have been* *disappointed, and I allow me directly to say a few words on that point. On my opinion the separation by Antonia C. Maury of the c- and ac- stars is the most important advancement in stellar classification since the trials by Vogel and Secchi. But in the new catalogue the spectra of some of them as Alpha Cygni and Delta Cephei are not even mentioned as peculiar. It is hardly exaggerated to say that the spectral classification now adopted is of similar value as a botany which divide the flowers according to their size and color. To neglect the c-properties in classifying stellar spectra, I think is nearly the same thing as if the zoologist, who had detected the deciding differences between a whale and a fish, would continue in classifying them together* (Mack, 1990). In Pickering's opinion the quality of the spectra was not sufficient to reveal such distinctions (Hoffleit, 1994).

Maury received more recognition for her investigations of spectroscopic binaries. The first of those stars, Mizar, was discovered by Pickering; Maury determined its period, and also found β Aur. Spectroscopic binaries became her main astronomical task: she published a detailed study on β Lyr in 1933 and inspected spectra taken of that star until 1948. After retirement she acted as curator of the Draper Park Museum in Hastings-on-Hudson, the old Draper Observatory in the original Draper estates (Hoffleit, 1952). She died in 1952 at the age of 86.

In 1943, Antonia Maury was awarded the Cannon prize. This Cannon Prize from the American Astronomical Society originates from money Miss Cannon has been rewarded with – the Ellen Richards Research Prize in 1932. Cannon turned that money over to the AAS in order to establish the Annie Jump Cannon Prize for women astronomers (Campbell, 1941). It is an irony of destiny that the only official appreciation Maury received was named after Cannon who successfully continued the work Antonia Maury had to abandon.

Some additional remarks: Maury's name is mentioned only twice in the HCO Annual Reports, in 1890 and in 1891 with respect to β Aur. At the turn of the century a series of articles was published in Popular Astronomy (Davis, 1898; McKenney, 1904) about women in astronomy. While the other Harvard ladies and their work are praised in those articles, Antonia Maury's name is only mentioned. This non-appreciation from the astronomical community lasted until her death – there is only one obituary written by Dorrit Hoffleit in Sky and Telescope while there exist more obituaries for the other Harvard ladies.

Annie Jump Cannon was born in Dover, Delaware in 1863. Her mother was a woman of Quaker training, her father a shipbuilder and state senator. She started her studies in 1880 at Wellesley College and graduated in the class of 1884 with the B.A. In Wellesley, Sarah F. Whiting (1846–1927) was the first female professor of physics; she had studied at MIT where she had met Pickering, who introduced her to astronomy. A decade after her graduation from Wellesley, Cannon returned for graduate studies in physics and astronomy, first at Wellesley, and in 1895 as special student in Radcliffe. At Radcliffe College Harvard faculty members taught female students. In 1896, Miss Cannon joined the staff of Harvard College Observatory. Pickering assigned to her the task of classifying stellar spectra of the southern sky. She obeyed his rules, did not fight the limits set by him and just worked. First she modified Fleming's classification system, which was less detailed than Miss Maury's system. She only retained the letters B, A, F, G, K and M indicating intermediate spectra by numbers representing tenths of intervals. The first volume of her Henry Draper Catalogue was published in 1918, Miss Cannon and Prof. Pickering being co-authors. 225 300 stars are contained in the catalogue, the classification being mainly done between 1911 and 1915. At that time she treated 5 000 spectra per month; including the extension of the catalogue, she classified about 350 000 stars. She worked with enormous speed and organized her work efficiently: she inspected the plates with a magnifying lens and called out her classifications to an assistant, who wrote them in a notebook. She was able to classify at a rate of more than 3 stars a minute; that rate was halved in stellar-rich dense areas (Welther, 1984). We also know that she could repeat the classification of any star to within a tenth of a subdivision of the original estimate. Her qualities were a keen visual memory, patience and discipline. She deserved the money paid to her: on the assumption of 35 cents per hour and a classification rate of 3 stars per minute one can estimate that the classification of 5 stars costed 1 cent.

Pickering was able to convince the astronomical community of the efficiency of that system. The way in which he did it is amusing: he used a meeting of the Solar Union, a kind of precursor of the IAU, which took place at Mount Wilson in 1907 just after a meeting of the Astronomical and Astrophysical Society of America in Harvard with many European participants. During a long train-ride, he had enough time to convince everybody of his ideas, the main task being that Karl Schwarzschild should give up the Potsdam classification system in favour of the Harvard system. At the Solar Union meeting, a Committee on the Classification of Stellar Spectra was constituted with Pickering as chairman. He got the strongest endorsement he could have desired, as he reported afterwards. With the approval of the IAU at its first meeting in 1922 in Rome the system was established with some extensions and modifications (Plotkin, 1990; Merrill, 1941).

Miss Cannon did not only work in the field of classification; she observed variable stars visually and photographically, discovered many new and unusual stars, 5 novae and about 300 variables. In 1907 she compiled a catalogue of 1380 variables, and in 1926, she published together with Townley and Campbell, a list with detailed data on 1760 long-period variables. She also maintained a card index of the literature of variable stars. In 1911 she was appointed curator of astronomical photographs after Mrs. Fleming's death. Reports about her work are given in the Annual Reports of the Director of HCO.

A nice little detail: in 1913 the meeting of the Solar Union took place in Bonn. Miss Cannon came to Europe, she was invited to speak at a meeting of the Royal Astronomical Society in London, and she also could attend the 24th meeting of the Astronomische Gesellschaft in Hamburg celebrating the 50th anniversary of the society. H.H. Turner (1913) at that time used to collect his impressions entitled: "From an Oxford Note Book": *It was a specially kind thought to send a general and cordial message to Bonn, inviting those who were not members of the Gesellschaft to be present at the meetings and to share the hospitality of Hamburg. Ladies, for instance are not yet eligible for actual membership, but the disability was rendered of small account at Hamburg.* From the records of the meeting of the Council - the so-called Vorstand of the Astronomische Gesellschaft - we do know, that there had been detailed and long discussions before that exception was made (Münzel, 1997).

Annie Jump Cannon really had a distinguished career: between 1918 and 1937, she was awarded six honorary doctoral degrees, including one by the University of Groningen and another by the most illustrious institution of the University of Oxford in 1925. This was the first time ever, for a woman, which probably meant most to her. In 1914, she was elected honorary member of the Royal Astronomical Society, in 1923 she was voted one of the 12 greatest living American women and in 1931 she received the Draper Award from the National Academy of Sciences presented to her by Harlow Shapley. Despite this worldwide recognition, it was not until 1938 that she got a permanent position at Harvard: she was appointed the William Cranch Board Astronomer with the rank of a professor. There she continued her work until a few weeks before her death on Easter Sunday in 1941.

The fourth remarkable Harvard women astronomer at the turn of the century was Henrietta Swan Leavitt, born in 1868, the daughter of a minister, receiving her degree from Radcliffe in 1892. In 1895/96 she worked as a volunteer and was hired by Pickering in 1902: he offered her a job paying 30 cents an hour. She worked there almost until her death in 1921. She studied photographs of the Magellanic Clouds, discovered 1777 new variable stars, determined periods of some of them and noticed a correlation between brightness and period, what we now call the period-luminosity relation for Cepheids. Pickering did not allow her to continue in that field: she had to do research in photographic photometry and she did that because of her sense of duty, justice and loyalty (Bailey, 1922). She established the Polar Sequence, published lists of sequences for 48 regions into which Pickering divided the sky in 1884, and established the standards of photographic magnitudes for the Astrographic Catalogue. She was, as Cecilia Payne-Gaposchkin said, *condemned by a harsh decision to uncongenial work* (Dobson & Bracher, 1992). Credit is given to her work in the Annual Reports; during the early years in the publications she got the standard acknowledgement, but she was the only author of those parts of Harvard Annals which contain results about the standard sequences. There is one outstanding attention her work received: in 1925 the Swedish Academy of Sciences recognised her contributions to be of such value that a nomination for the 1925 Nobel Prize would be justified. Unfortunately she had died four years too early – Nobel Prizes are awarded to living persons only. H. Shapley (1923) in the seventy-seventh Annual Report of the Director of the HCO states that by her death *the Observatory lost an investigator of the highest value.*

Just for the sake of completeness I would like to mention a few more names: Winnifred Edgerton (1862–1951), who graduated from Wellesley in 1883, fought long and hard to be admitted to attend Columbia University. In 1886, she was the first American woman to earn a Ph.D. in astronomy. Her thesis was strictly in mathematics and did not even mention an application to astronomy. She got the permission to study astronomy under the condition that it has to be understood clearly that this should not establish a precedent for women to enter Columbia. After her marriage to a geologist she had to behave properly: she engaged in social activities and raised four children. She was on a Committee that founded Columbia's sister college, Barnard, in 1889 (Dobson & Bracher, 1992; Hoffleit, 1994).

Quite a different training had Dorothea Klumpke (1861–1942), since 1901 Mrs. Isaac Roberts. She was born in San Francisco, where at that time no institution for educating girls in the same way as boys did yet exist. Her parents, being of German background, decided to bring their children back to Europe. She had been in schools in Germany, Switzerland and France, received a bachelor of science degree in mathematics in 1886 and was the very first woman to earn a Ph.D. in 1893 at the Sorbonne in Paris. She was a research astronomer: until 1934 she was employed intermittently at the Observatory of the University of Paris, where she supervised the measurements of the plates of the Paris Zone of the Carte du Ciel and the preparation of the corresponding charts. After her return to the States, she became a Patroness of the Astronomical Society of the Pacific (Aitken, 1942; Bracher, 1981; Reynolds, 1944; Weitzenhoffer, 1986). In 1899 she spoke before the International Congress of Women in London about "The Work of Women in Astronomy" (Klumpke, 1899). In 1889 she was awarded with the first Prix des Dames of the Société Astronomique de France, in 1893 she was elected Officier d'Académie by the Paris Academy of Sciences and in 1934, Chevalier de la Légion d'Honneur.

The Project of the Carte Du Ciel offered job opportunities to women at many observatories, but mostly because of the low cost of them. The system of lady computers was also established at Greenwich Observatory after 1881; the most famous names are Alice Everett and Annie Russel (Brück, 1994; 1995). Both were educated in Belfast schools and at Girton College in Cambridge. Alice Everett had a short career also in Germany, working as the first woman at Potsdam from 1895 for three years, replacing A. Schwassmann while he was away on military service. Afterwards she was employed for one year at the observatory of Vassar College and applied for a position at Lick, which she did not get because of lack of funding. She returned to England and had to leave astronomy.

Those tiny parts of the story of pioneer women scientists show that in their very personal way, they tried not to be passive victims of discrimination. They made significant contributions working within boundaries and fighting to expand those boundaries. The situation has changed in many aspects, at least in science; in many countries discrimination is forbidden by law and efforts are made for equal opportunity. But – if one considers the employment situation – women still carry out two thirds of the worldwide labour, earning one tenth of the worldwide income.

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