THE HARVARD COMPUTERS



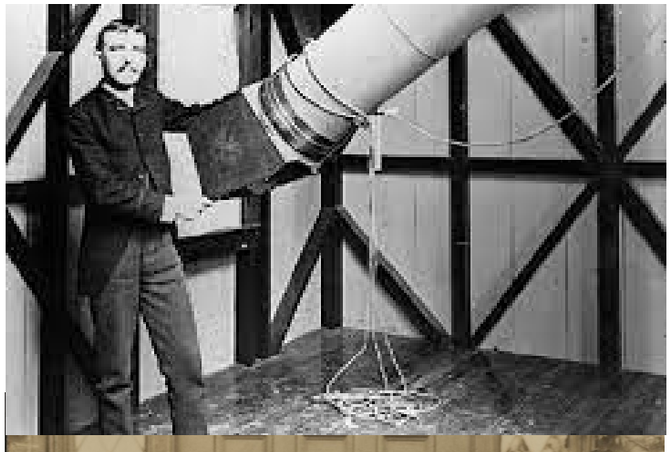


The “women computers” were a group of approximately 80 women who used astrophotography to analyze the data from the Harvard Observatory, under the direction of Dr. Edward Pickering from 1877 until his death in 1919. However, these figures do not include the volunteers and student assistants who were conducting this work before the first computers were officially hired.Women were not allowed to use the telescopes at the university because the work was considered to be too physically demanding to be carried out by females.Data analysis was considered to be “clerical” in nature.

Women were paid 25-50 cents per hour, considerably less than their male counterparts and on par with what factory or domestic workers earned at the time.This meant that for the same money a larger female staff could be hired to process more information than a male staff. Before her death, Williamina Fleming worked 60 hours a week, 6 days a week, managing the staff of computers while also serving as the observatory’s chief writer—and earned only $1500 annually or approximately 48 cents an hour. While she did push Pickering for better wages, he argued that she was paid well for a woman - ignoring her argument that her male counterparts were, upon being hired, paid at least 40% more.

Computers performed a variety of tasks, including reducing photos to make images clearer, classifying stars by comparing photos to known catalogs, cataloging photos, noting an image’s date of exposure and region of the sky, and copying notes and data into tables to include a star’s location in the sky, and their magnitude. Women were discouraged from doing theoretical work, and many of their discoveries were later attributed to male astronomers.

HENRY DRAPER CATALOGUE





The major project of the Harvard computer team was the Henry Draper Catalogue, which had the goal of mapping and defining every star in the universe, and was funded by Anna Draper in honor of her late husband Henry.It is through this project that many of the team's most famous discoveries were made possible. Work on the project began in 1890 and eventually included the classification of over 225,000 stars.

Project's Notable Scientists:

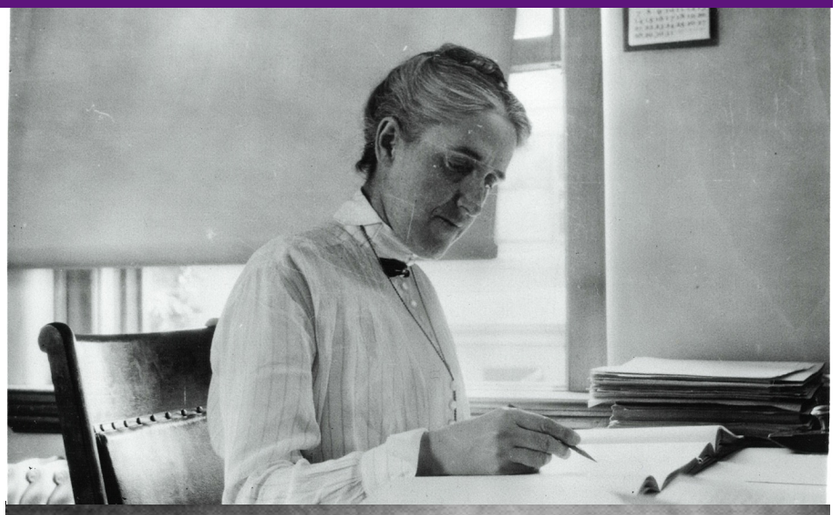
*Henrietta Swan Leavitt, who focused on cepheid stars, and discovered the period-luminosity relationship, which allows us to calculate the distance to stars, and even other galaxies

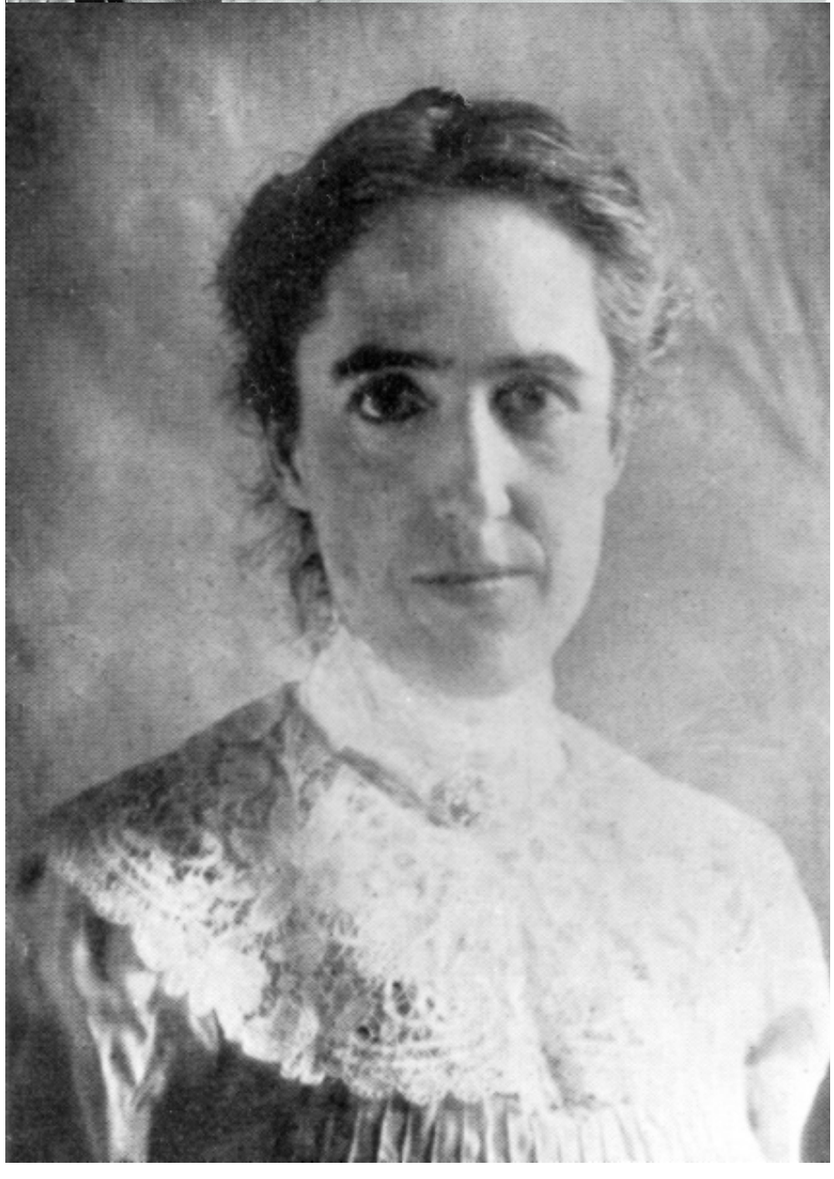
*Annie Jump Cannon, who created the stellar classification system and manually classified more stars in a lifetime than anyone else, with a total of around 350,000 stars. She discovered 300 variable stars, five novae, and one spectroscopic binary, creating a bibliography that included about 200,000 references

*Cecilia Payne, who discovered that the sun was mostly hydrogen
Antonia Maury, who figured out the relative size of stars from their spectra & discovered the first spectral evidence of a binary star

*Florence Cushman, who determined the positions and magnitudes of the stars listed in the 1918 edition of the Henry Draper Catalogue (which featured the spectra of roughly 222,000 stars)

*Williamina Fleming, who discovered 310 variable stars, 59 nebulae, and the first white dwarf star.





HENRIETTA SWAN LEAVITT

Henrietta Swan Leavitt was born in Massachusetts in 1868, the eldest of seven children.After a childhood illness believed to be scarlet fever, she was left with severe hearing damage for most of her life.She received her bachelor's degree in 1882 from Radcliffe College, the female counterpart to Harvard University.While studying for her master's degree in 1893, she went to work under the direction of Dr. Edward Pickering at the Harvard Observatory as a computer.Much of her work there concentrated on Cepheid variables, stars that go through periods of relative brightness and dimness. In her published 1908 paper, "1777 Variables in Magellanic Clouds," she explained that the longer the cycle, the greater the brightness. This was known as the "period luminosity relation" and later as "Leavitt's Law," and was used to measure the distance of stars. Later in her 1912 paper "Periods of 25 Variable Stars in the Small Magellanic Cloud," in which she confirmed her previous findings, other astronomers began using these variables as standards. Her discoveries paved the way for the Universe to be measured and mapped, and for Edwin Hubble to discover that the universe is expanding.A Swedish mathematician, Gösta Mittag-Leffler, tried to nominate her for a Nobel Prize for her work, only to discover she had died from cancer three years earlier, in 1921.

Leavitt discovered over 2400 variable stars in her career, about half of the known total in her life.





ANNIE JUMP CANNON

Annie Jump Cannon was encouraged by her parents, especially her mother, to take an interest in science at a young age.She pursued her education in science and math, and graduated as valedictorian at Wellesley College with a major in Physics. Following college, she focused on photography and traveling and even published a book of photography in 1893 as a souvenir for the World Fair in Chicago.She returned to Wellesley for graduate studies in astronomy after her mother, who inspired her love of science, passed away. Cannon then enrolled in classes at Radcliffe College so she could use Harvard's telescopes.In 1896, she became one of the "women computers" at the Harvard Observatory, where she settled a debate on how to classify stars by their color, temperature, and size.This system became known as the Harvard Standard and was officially adopted by the International Astronomical Union in 1922.The system is still used today with minor changes.In 1901, she became Head of Photometry after her first paper was published.She classified over 350,000 stars in her lifetime – a record she still holds today – and discovered 300 variable stars, five novas, and one binary system.She was the first woman to receive a doctorate degree in astronomy from Groningen University and the first to receive the Henry Draper Medal of Honor from the National Academy of Sciences in 1931.When she received the Ellen Richards Research Prize, she gave it to the American Astronomers' Society to create an annual award for the year's most prominent female in the field, which is called the Annie Jump Cannon Prize.Not only did she make lasting contributions to astronomy, she tirelessly championed equal rights for women.She took part in the suffragist movement and represented working women at the 1933 World Fair.She was the first woman to be appointed the William C. Bond Chair of Astronomy at Harvard University and was still classifying stars at the observatory until she died at the age of 77.

At her peak, Cannon count classify three stars per minute.





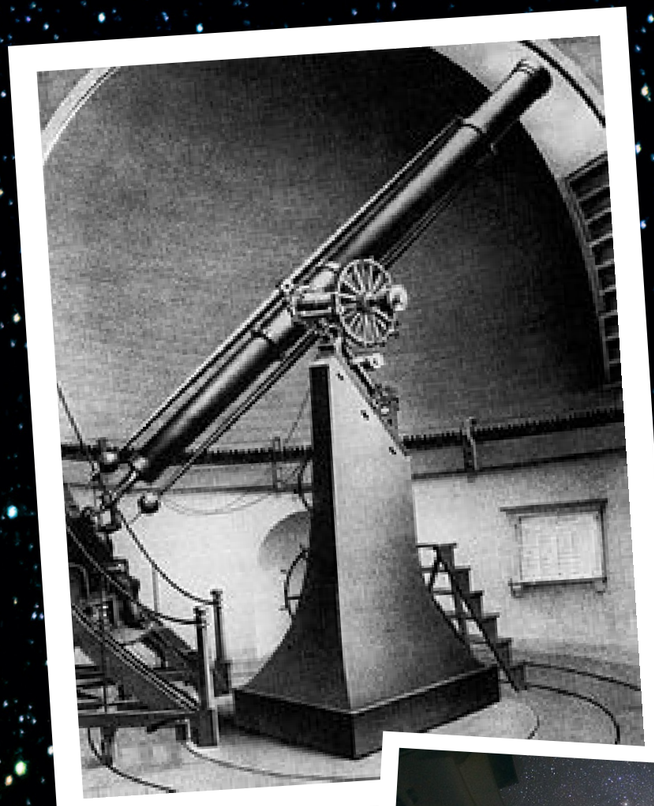
WILLIAMINA FLEMING

Williamina Fleming was born in Scotland and took a job as a pupil-teacher at the age of 14 to help support her large family after her father's death. In 1878, she emigrated to the United States.Soon after though, she found herself pregnant and abandoned by her husband in a new country and took a job to work as a maid in Dr. Edward Pickering's home, where she impressed her employers. After Pickering became unsatisfied with the work of his male staff, he declared his maid could do a better job.Thus, he hired Fleming to work as a computer at the Harvard Observatory. She developed a complex system to classify stars that was later improved upon by her colleague Annie Jump Cannon. When the group began working on the Henry Draper Catalogue of stars, she classified over 10,000 stars in nine years. She discovered more than 300 variable stars, 59 gaseous nebulae, ten novae, and the Horsehead Nebula located in Orion's belt, as well as becoming one of the first to recognize the existence of white dwarf stars. Additionally, she served as the observatory's writer, editor, and proofreader for their research papers, reports, data tables, and books. In 1899, she became the Curator of Astronomical Photographs at Harvard and managed dozens of other computers at the observatory.She was the first American woman granted honorary membership into the Royal Astronomical Society.

"Women who have taken up any branch of science need not be discouraged, even if others refuse to give credit to their work. Labor honestly, conscientiously and steadily, and recognition and success must crown your efforts in the end."

– Williamina Fleming

THE SCIENCE of the skies



THE GREAT REFRACTOR: 15" telescope installed in 1847, crucial in such discoveries as the eighth satellite of Saturn in 1848 and was used to take one of the earliest photographs of a double star in 1857. Once Pickering took over the Observatory, it was used almost exclusively for photometry.



RADCLIFFE COLLEGE: Harvard-affiliated all-female collegiate institution. Harvard did not officially admit female students until 1972. Now known as the Radcliffe Institute for Advanced Study at Harvard University.It is one of the world's leading centers for interdisciplinary research.

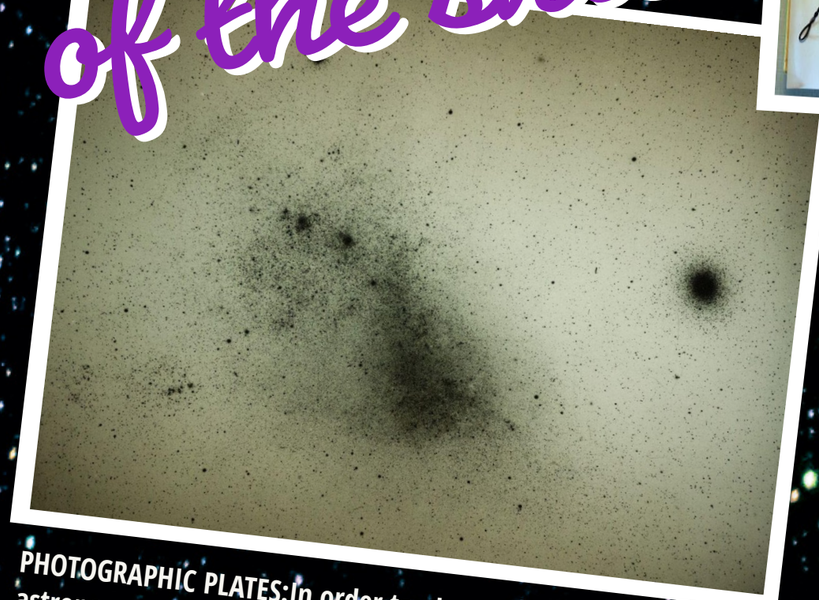


PHOTOMETRY: In astronomy; the measurement of the brightness of stars, nebulae, galaxies, planets, etc. Primarily athieved by gathering light into a telescope and then capturing and recording the light on photosensitive plates, the basic calculations of photometry included visual comparison between these images.By using filters astronomers can obtain values that allow them to determine the color and temperature of a star.

THE SCIENCE of the skies

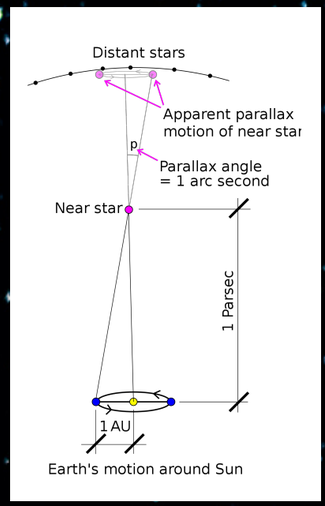


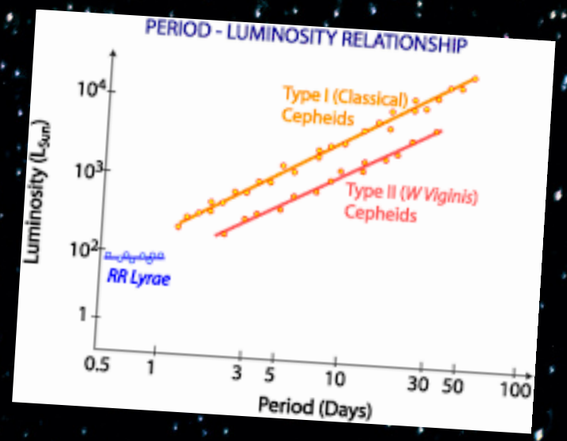
FLY SPANKER: A tool used to help standardize brightness measurements was invented by Henrietta Leavitt.Previously, brightness had been measured by observers ranking it by eye, which was too subjective for an accurate measurement.The "fly spanker" was a piece of photographic plate with a wire handle attached which had stars of well-established brightnesses on it.This tool could be moved around in front of a glass plate with stars of unknown brightness to help standardize the measurements and to determine if the brightness of a star had changed.



PHOTOGRAPHIC PLATES:In order to photograph the stars, astronomers attached a glass plate to the end of a telescope. Starlight accumulated on the plate photon by photon during a time exposure.Stars appeared as black dots on the finished plates. Nebulae appeared as gray smears.Pickering added to this process a new element:in order to capture the colored light emitted by the stars, he placed a large prism in front of the photographic plate. The astronomers could then stack the plates on top of each other to measure and observe the movement of the stars over time. Harvard continued to make photographic plates of the stars until 1989.The Harvard Observatory has a collection of over 500,000 plates which are being digitized today along with the notebooks of the women computers.

STELLAR PARALLAX:It is possible to measure the distance of stars that are relatively close to Earth by calculating stellar parallax. This method was first used by the Greek astronomer Hipparchus in 189 BC, and it is still used today. As the Earth orbits the Sun, close stars appear to move in the sky, while distant stars remain static in the background. This illusory movement is called parallax. To use this method, astronomers measure a nearby star's position in relation to the fixed stars. Then they repeat that measurement at a later time. By comparing the two calculated angles, it is possible to calculate the star's distance from the observer.





THE LEAVITT LAW: Because they do not move, calculating the distance of more distant stars is challenging. Henrietta Leavitt realized that Cepheids change over time which can be measured. She observed that the period of time between a Cepheid's brightest and dimmest nights was directly related to its intrinsic luminosity. By graphing the activity of the Cepheids, Leavitt showed that the brightest stars had the longest periods.Now if you could determine the length of a Cepheid's period, you could calculate its intrinsic brightness, which could then be compared to its apparent brightness to determine its Distance.

THE SCIENCE of the skies



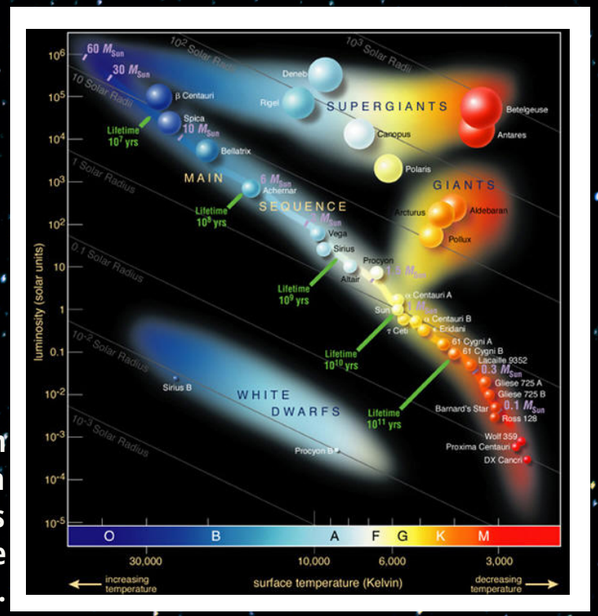
SMALL MAGELLANIC CLOUD: A dwarf galaxy near the Milky Way. Classified as a Dwarf Irregular Galaxy, it is about 7,000 light years across.Between 1893 and 1906, the 24-inch telescope installed in Peru and run by the Harvard College Observatory collected plates observing both the large and small Magellanic clouds.



CEPHEID STARS: Stars that have entered a stage of their life cycle that involves a repetitive 'pulsing' cycle of lighter and darker appearance. These cycles can last anywhere from 1-40 days, with the brightest Cepheid stars taking longer than the faintest.This relationship between the rate at which the stars 'pulse' and how bright they appear to us gives a very handy way to measure how far away they are.This is the "measuring stick" for the universe that Henrietta discovered.



BINARY STARS:Binary stars are two stars orbiting a common center of mass. The brighter star is officially classified as the primary star, while the dimmer of the two is the secondary star (classified as A and B respectively). In cases where the stars are of equal brightness, the designation given by the discoverer is respected.A high proportion, perhaps as high as 85% by some estimates, of all stars in the Milky Way Galaxy are binaries or members of more complex multiple systems.



HARVARD SPECTRAL CLASSIFICATION: A system of classifying stars based on the observed color of that star. Annie Cannon looked at the Balmer Absorption Lines (a measure of what colors of light are absorbed by a star and which are reflected, from which we can infer color) and classified the different stars based on that. It was later discovered that the color of a star was also related to heat and size, thus these qualities have been retroactively correlated with this classification system. The pneumonic device for remembering the letters used for these classifications (OBAFGKM) is Oh Be A Fine Girl Kiss Me.







The World of Silent Sky

1839

The Harvard Observatory is established.

1847

The “Great Refractor” telescope is mounted in the observatory building.

1869

The National Woman Suffrage Association and the American Woman Suffrage Association are founded.

1877

Edward Pickering becomes the fourth director of the observatory.

1879

Williamina Fleming is hired by Edward Pickering as a maid.

1881

Williamina Fleming becomes a permanent member of the observatory staff.

1882

Both the U.S. House and Senate appoint committees on women’s suffrage; each report favorably.







1884

The U.S. House of Representatives debates women's suffrage.

1886

Anna Draper funds the photography of stellar spectra in honor of her late husband, Henry Draper.

The suffrage amendment is defeated two to one in the U.S. Senate.

1888

Williamina Fleming discovers the Horsehead Nebula.

1890

The National Woman Suffrage Association and the American Woman Suffrage Association merge to form the National American Woman Suffrage Association. Its first president is Elizabeth Cady Stanton. The focus turns to working at the state level. Wyoming renews general woman suffrage.

1893

Henrietta Leavitt begins work at Harvard Observatory.







1894

Despite 600,000 signatures, a petition for woman suffrage is ignored in New York.

1895

The New York State Association Opposed to Woman Suffrage is founded.

1896

Annie Jump Cannon joins the observatory as a research assistant.

1899

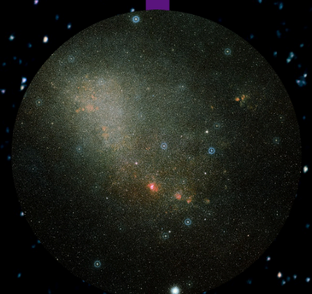
Williamina Fleming becomes the Curator of Astronomical Photographs at Harvard.

1901

Annie Jump Cannon publishes her first catalog of stellar spectra and is appointed Head of Photometry at Harvard.

1903

Henrietta Leavitt returns to the observatory as a full-time employee after a two year absence.







1905

Einstein publishes four papers that become major contributions to the foundation of modern physics. They revolutionize science's understanding of the fundamental concepts of space, time, mass, and energy.

Henrietta Leavitt first discovers large numbers of Cepheids in the Magellanic Clouds.

1906

Elizabeth Cady Stanton's daughter, Harriot Stanton Blatch, returns from England and forms the Equality League of Self Supporting Women with a membership based on professional and industrial working women. It initiates the practice of holding suffrage parades.

Williamina Fleming becomes the first female granted honorary membership into the Royal Astronomical Society.

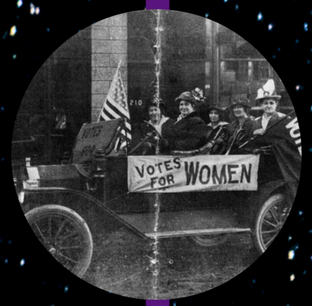
1907

Williamina Fleming publishes a list of 22 stars she has discovered.

1908

Henrietta Leavitt first publishes her discovery of "1777 Variables in the Magellanic Clouds", noting a pattern in variable stars (cepheids).







1910

Emulating the grassroots tactics of labor activists, the Women's Political Union organizes America's first large-scale suffrage parade, which is held in New York City.

1911

Williamina Fleming dies.

1912

Henrietta Leavitt publishes a full paper "Periods of 25 Variable Stars in the Small Magellanic Cloud" documenting her Period-Luminosity relationship (later called the Leavitt's Law).

1913

Ejnar Hertzsprung uses Leavitt's finding to measure distance to cepheids within the Milky Way.

The Senate votes on a women's suffrage amendment but fails to pass.

1914

Montana grants suffrage to women.

World War I starts with the assassination of Archduke Franz Ferdinand of Austria.







1915

Albert Einstein publishes the equations of general relativity.

1916

Woodrow Wilson promises that the Democratic Party Platform will endorse women's suffrage.

Montana elects suffragist Jeannette Rankin to the House of Representatives. She is the first woman elected to the U.S. Congress.

1917

Beginning in January, the National Woman's Party posts the Silent Sentinels at the White House - the first group to picket the White House. In June, arrests begin. Nearly 500 women are arrested (most for "obstructing traffic"), and 168 women serve jail time. Alice Paul was sentenced to seven months in jail and staged a hunger strike in protest. The women demanded to be treated as political prisoners.Doctors force-fed her and threatened to send Paul to an insane asylum.Newspaper accounts of her treatment garnered public sympathy and support for suffrage.

The United States declares war against Germany, entering WWI.

The New York state constitution grants suffrage to women. New York is the first Eastern state to fully enfranchise women.







1918

President Woodrow Wilson announced his support for suffrage.

Alice Paul and other suffragettes are released from prison as a court rules that the arrests were illegal.

The Nineteenth Amendment to the U.S. Constitution (to grant women suffrage) passes the U.S. House with exactly a two-thirds vote but loses by two votes in the Senate.

World War I ends.

1919

Edward Pickering dies.

1920

Henrietta Leavitt is made head of Stellar Photometry at Harvard Observatory.

The Nineteenth Amendment to the U.S. Constitution is ratified, stating, "The right of citizens of the United States to vote shall not be denied or abridged by the United States or by any State on account of sex”.

Harlow Shapley and Heber Curtis debate the scale of the universe.







1921

Harlow Shapley is named fifth director of the observatory.

Henrietta Leavitt dies of ovarian cancer.

1922

Annie Jump Cannon's classification system of stars is officially adopted by the International Astronomical Union.

1923-24

Edwin Hubble measures Cepheids in the Andromeda Galaxy, proving that the universe is far bigger than the Milky Way.

1931

Annie Jump Cannon receives the Henry Draper Medal of Honor from the National Academy of Sciences.

1938

Annie Jump Cannon is the first woman named the William C. Bond Chair of Astronomy at Harvard University.

1939

Germany invades Poland, officially starting World War II.

1941

Annie Jump Cannon dies.