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ZOOM in on america

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They Explained the Cosmos

They defied all odds and overcame all obstacles that contemporary society put in the way of women scientists. They were observers and discoverers, they made calculations and spent days, months, and years looking through telescopes' eyepieces towards stars and galaxies, comparing photographs, measuring distances, temperatures, and compositions. They were refused top positions, were not employed by some observatories, and, last but not least, could not hope for equal pay. And yet, they prevailed. They followed their dreams. They answered the call that was within them - the call of the stars. Read about the women astronomers of the nineteenth and early twentieth century whose work was essential to our present understanding of the cosmos.

Maria Mitchell (1818 - 1889)

Maria Mitchell was the first female American astronomer, one of the most famous scientists of her day, the first woman Professor of Astronomy of Vassar College, the first woman elected as Fellow of the American Academy of Arts and Sciences, and the American Association for the Advancement of Science. Two quotes attributed to her, give an apt description of what a scientist, explorer, and discoverer should be like:

Do not look at stars as bright spots only - try to take in the vastness of the universe.
We especially need imagination in science. Question everything.

Mitchell is best known for her discovery of a comet in 1847 and calculating the comet's orbit. The comet was named in her honor "Miss Mitchell's Comet", or "C/1847 T1" and the feat brought her international fame. Yet, this discovery was not accidental; she was devoted to scientific research and education all her life.

Maria Mitchell was born in Nantucket, Massachusetts, near Cape Cod. It was her father, William Mitchell, a schoolteacher, and amateur astronomer, who instilled an interest in science in her, while she was still a very young child. He taught her how to observe the sky and operate astronomical instruments such as chronometers, sextants, and telescopes. She was a student and a teaching assistant to her father in a school he founded.

Her discovery of a comet launched her career as an astronomer. In 1849, she was offered a position for the U.S. Coast Survey at the U.S. Nautical Almanac Office. She tracked the movements of the planets - particularly Venus - and compiled tables of their positions to assist sailors in navigation.

In 1865, she was employed as a professor of astronomy and director of the college observatory at Vassar - the second degree-granting institution of higher education for women and one of the first elite women's colleges in the U.S. (also known as one of the "Seven Sisters") - where Mitchell taught with great success for over 20 years.

Mitchell pursued her own research alongside teaching. She took pictures of planets, including Jupiter and Saturn, and their moons, studied nebulae, double stars, and solar eclipses. Themes that caught her attention included the revolution of one star around another in double star formations and the influence of distance and chemical composition in star color variation. She recorded sunspots first by eye and then began photographing them daily, thus taking the first regular photographs of the sun.

In 1873, she founded the Association for the Advancement of Women.

A storm of comets: This artist's conception illustrates a storm of comets around a star near our own, called Eta Corvi
Image NASA/JPL-Caltech

Williamina Fleming (1857 – 1911)

Williamina Fleming was born in Scotland and moved to the United States with her husband Orr Fleming. He abandoned her soon after and she had to find work to support herself and their little son. She found employment as a maid in the home of the director of the Harvard College Observatory, Professor Edward Pickering. His wife believed Williamina was a clever young woman who might help her husband in the Observatory. Williamina was 22 when she joined the Harvard Observatory, based on this recommendation, and worked there for the next 34 years. At first, she was given administrative work, but was later assigned the more scientific task of analyzing stellar spectra.

In this way, Williamina became one of the founding members of the Harvard Computers, an all-women team of human computers whom Edward Pickering hired to compute mathematical classifications and edit the observatory's publications. Pickering believed that instead of relying solely on observations made by telescope, there is a need to examine photographs. Today, this kind of observation is known as astrophotography, whereby photos are taken with a camera attached to a telescope.

During her career at the Harvard Observatory, Williamina helped develop a common designation system for stars and cataloged thousands of stars and other astronomical phenomena.

Cataloging was tiresome, if not tedious, as she described in her diary: "In the Astrophotographic building of the Observatory, 12 women, including myself, are engaged in the care of the photographs…. From day to day my duties at the Observatory are so nearly alike that there will be little to describe outside ordinary routine work of measurement, examination of photographs, and of work involved in the reduction of these observations."

Fleming examined the spectra of more than 10,000 stars and developed a classification system containing 22 classes. Her work was carried even further by Antonia Maury, who developed her own classification system, and later by Annie Jump Cannon.

The Harvard Observatory women's team employed more than 80 during Pickering's time in office, from 1877 until his death in 1919. They all worked computing and cataloging data. Some of these women, like Williamina, produced significant work on their own. During her career, she discovered a total of 59 gaseous nebulae, over 310 variable stars, and 10 novae, as well as white dwarfs. In 1888, she discovered the famous Horsehead Nebula.

Fleming published her discovery of white dwarf stars in 1910. Her other publications include *A Photographic Study of Variable Stars* (1907), a list of 222 variable stars she had discovered; and *Spectra and Photographic Magnitudes of Stars in Standard Regions* (1911).

This frame from an animation shows the merger of two white dwarfs. A white dwarf is an extremely dense remnant of a star that can no longer burn nuclear fuel at its core. Image NASA/JPL-Caltech

Annie Jump Cannon (1863 – 1941)

Do you think that cataloging 350,000 stars would be an impossible task for just one person? Not for Annie Jump Cannon, who would prove that it was totally achievable.

Cannon was born in Dover, Delaware and it was likely her mother, Mary Jump, who instilled the love of stars in her, when they gazed together at the night sky trying to identify them. Annie earned a degree in physics at Wellesley College, a private women's liberal arts college in Wellesley, Massachusetts. The college, founded in 1870, is a member of the original Seven Sisters Colleges, an unofficial grouping of elite women's colleges in northeastern United States.

In 1894, Cannon worked at Wellesley as a junior physics teacher and became a "special student" of astronomy at Radcliffe.

A breakthrough in her career came in 1896 when she joined the so-called "Pickering Women", a group of women hired by Harvard College Observatory Director Edward Pickering to carry out astronomical calculations. Cannon worked at the Harvard College Observatory for over 40 years.

Her outstanding performance led to the naming and cataloging of about 350,000 stars and to streamlining the universal stellar classification. She was a theorist of star spectra. The spectral classification of stars was given letters O B A F G K M - a sequence from the hottest (O type) to the coolest (M type). For astronomers to learn this classification, a mnemonic phrase was used: Oh, Be A Fine Girl - Kiss Me!

The goal of cataloging the stars was to obtain optical spectra of stars, then index and classify them by their spectra. It was then a matter of great importance regarding the development of a classification scheme.

Before Cannon was in charge of the classification, three other women worked on the task, and each devised a different approach. These women were Nettie Farrar, Williamina Fleming, and Antonia Maury. Annie Jump Cannon's scheme was the division of stars.

Annie Jump Cannon continued the work of her predecessors. Her contribution to the Henry Draper Catalogue - a list of nearly 360,000 stars with their positions, magnitudes, and spectral types - is considered the largest accumulation of astronomical information ever assembled by one scientist.

Cannon also published catalogs of variable stars (including 300 she discovered).

During her long career, Cannon paved the way for other female researchers. She was the first recipient of an honorary doctorate from Oxford and the first woman elected as an officer of the American Astronomical Society. In 1938, she finally obtained a regular appointment from Harvard as William C. Bond Astronomer.

A faraway nebula, or a cloud of gas and dust in space amd multiple clusters of stars born from the same dense clumps of gas and dust. Image NASA/JPL-Caltech

Henrietta Swan Leavitt (1868 – 1921)

Measuring the distances of stars in other galaxies from Earth was of utmost importance in our study of the cosmos. In this respect, we are indebted to Henrietta Swan Leavitt and her work in calibrating the photographic magnitudes of stars to which all other stars could be compared. In this way, we understand the relative brightness and variability of stars.

Henrietta Swan Leavitt was born in Lancaster, Massachusetts. She was the daughter of a Congregational church minister. She attended Harvard University's Society for the Collegiate Instruction of Women, where she earned a B.A. degree.

She joined Edward Pickering's women "computers" team at the Harvard College Observatory. Her duty was to measure and catalog the brightness of stars as they appeared in the observatory's photographic plate collection. Leavitt discovered and cataloged more than 1500 variable stars (these are stars whose brightness, as seen from Earth, fluctuates) in the nearby Magellanic Clouds, small galaxies next to the Milky Way. She observed that brighter Cepheid variable stars (a type of star that pulsates radially, varying in both diameter and temperature and producing changes in brightness with a well-defined stable period and amplitude) take longer to vary, information used today to calibrate the distance scale of our universe.

In 1908, Leavitt published her results in the Annals of the Astronomical Observatory of Harvard College.

After her death, Edwin Hubble used Leavitt's period-luminosity relation, together with the galactic spectral shifts, to establish that the universe is expanding.

Large Magellanic Cloud is a satellite galaxy of the Milky Way nearly 200,000 light-years from Earth
Image ESA/NASA/Hubble

Cecilia Helena Payne-Gaposchkin (1900 – 1979)

Stars are made of hydrogen and helium.

This extremely important discovery in astronomy was made by Cecilia Payne-Gaposchkin, but her contributions to the development of astronomy do not end there. She also discovered that stars could be classified according to their temperatures. Payne's thesis titled "Stellar Atmospheres, a Contribution to the Observational Study of High Temperature in the Reversing Layers of Stars" (1925) was recognized as "undoubtedly the most brilliant Ph.D. thesis written in astronomy," by distinguished astronomers Otto Struve and Velta Zebergs.

Cecilia Payne was born in England and encouraged to become a pianist like her father and sister, Florence. However, Cecilia was more interested in learning about science. Her first choices of botany, physics, and chemistry, however, were ultimately outdone by her fascination with astronomy. Payne's interest in the field began when she first listened to a lecture by Arthur Eddington, who explained Einstein's theory of relativity. Cecilia said this about the lecture: "The result was a complete transformation of my world picture." She went on to study astronomy at Newnham College in Cambridge University, but was not awarded a degree because Cambridge did not grant degrees to women until 1948.

Payne understood that there were more opportunities for a woman to work in astronomy in the United States than in Britain, so she decided to move to America. In 1931 she became an American citizen.

She received a fellowship to study at the Harvard College Observatory in Cambridge, Massachusetts in 1923. After completing her doctorate, Payne worked at Harvard as a technical assistant. However, in that capacity, she was unable to carry out her work on stellar spectra. Instead, Payne obliged her superior, who encouraged her to work on the photometry of stars by using photographic plates. During this pursuit, Payne's interest shifted to variable stars and novae, studying and researching their explosions. She also wrote a book titled *Stars of High Luminosity*, (1930) based on her stellar spectral work.

In 1934 Payne married Russian-born astronomer Sergei Gaposchkin, who was also interested in the study of variable stars. They settled in the historic town of Lexington, Massachusetts, a short distance from Harvard, where they both worked.

In 1956, Payne-Gaposchkin became the first woman to be promoted to full professor from within the faculty at Harvard's Faculty of Arts and Sciences. Later, she also became the first woman to head a department at Harvard, when she was appointed the Chair of the Department of Astronomy.

She authored several books on astronomy including *The Variable Stars* (1938), *Variable Stars and Galactic Structure* (1954), and *The Galactic Novae* (1957).

LL Ori and the Orion Nebula
Image NASA, ESA and the Hubble Heritage Team

ACTIVITY PAGE

ACTIVITY 1: READING COMPREHENSION

Read the stories about women astronomers in this issue of *Zoom*. Then decide if the sentences below are true (T) or false (F).

Are these sentences true (T) or false (F)?

1. Miss Mitchell's Comet was formally designated C/1847 T1.

2. Before Williamina Fleming was employed at the Harvard Observatory she had worked as a maid.

3. In all 50 women worked for the director of the Harvard Observatory Edward Pickering computing and cataloging data.

4. Cecilia Payne's Ph.D. thesis was recognized as "undoubtedly the most brilliant Ph.D. thesis written in astronomy," by distinguished astronomers Otto Struve and Velta Zebergs.

5. Cecilia Payne's greatest discovery was that stars are made of hydrogen and helium.

6. A mnemonic phrase for the spectral classification of stars O B A F G K M was: Oh, Be A Fine Girl - Kiss Me!

7. Henrietta Swan Leavitt worked on calibrating the photographic magnitudes of stars to which all other stars could be compared.

8. Annie Jump Cannon discovered 300 stars.

9. Maria Mitchell said: *We especially need imagination in science. Question everything.*

10. Cecilia Helena Payne-Gaposchkin died in 1900.

11. Henrietta Swan Leavitt never joined Edward Pickering's women "computers" team.

12. Willamina Fleming, Antonia Maury and Annie Jump Cannon all worked on the Henry Draper Catalogue.

NOVEMBER-DECEMBER 2020

TRIVIA QUESTION

Who was the first American woman astronomer?

Send the answer (with your home address) to:
KrakowAIRC@state.gov
The 1st, the 6th and the 15th sender of the correct answer will be awarded with a book prize.

Deadline December 30, 2020

September-October Quiz Answer:

Jacqueline Cochran

The winners are:

Maya from Gliwice, Marta from Boleslawiec, and Agnieszka from Krakow

CONGRATULATIONS!!!

The prizes will be sent to you by mail.

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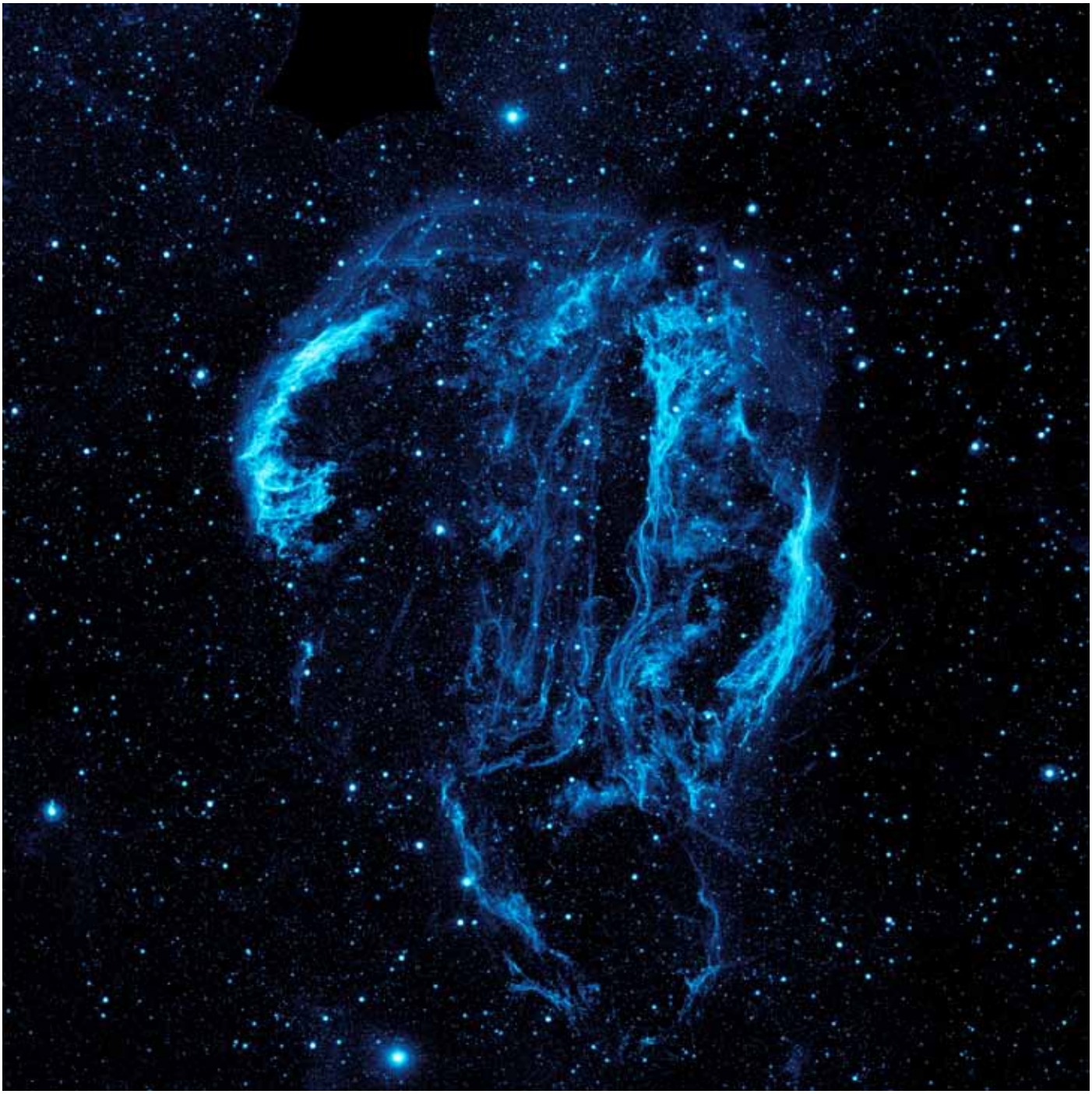

An ultraviolet image of the Cygnus Loop Nebula, taken by NASA's Galaxy Evolution Explorer. The nebula lies about 1,500 light-years away, and is a supernova remnant, left over from a massive stellar explosion that occurred 5,000-8,000 years ago. The Cygnus Loop extends more than three times the size of the full moon in the night sky, and is tucked next to one of the 'swan's wings' in the constellation of Cygnus.

The filaments of gas and dust visible here in ultraviolet light were heated by the shockwave from the supernova, which is still spreading outward from the original explosion. The original supernova would have been bright enough to be seen clearly from Earth with the naked eye.

Image NASA/JPL-Caltech

On the front cover: Pegasus from The beauty of the heavens : a pictorial display of the astronomical phenomena of the universe. Creator: Blunt, Charles F. Image Smithsonian Institution