

Astronomy Becomes Science

In 1610, Galileo pointed the first telescope at the night sky and started a revolution in astronomy. Caroline Herschel furthered that revolution through a lifetime spent helping her brother William build bigger and better telescopes. And, by establishing a regular, systematic schedule of observing the night sky and carefully recording all data, Caroline changed the very nature of observational astronomy.

*Her fame will be held
in honour through all ages.*

French astronomer Pierre-Francois-Andre Mechain



**CAROLINE
LUCRETIA
HERSCHEL**

born 1750

died 1848

Fourteen-year-old Caroline Herschel stood on tiptoe and peeked out the window into the courtyard below. She wished she could be down there with her father and her brother William. Her mother had given her a long list of chores to do this morning. She hoped she could finish in time.

Caroline watched as Papa and Willie helped some of the younger Herschel boys fill a large tub with water. Today Hanover, Germany, the city where the Herschels lived, would see a total eclipse of the Sun. For several minutes the Moon would be directly between the Earth and Sun. The Sun would vanish completely, except for a glowing halo. People who stared directly



Caroline Herschel's father knew that looking directly at the Sun could damage his children's eyes. In order for his children to see the eclipse without looking at the Sun, Isaac Herschel used a tub of water as a mirror. The family could watch the eclipse in reflection.

Using a pinhole camera is another way to watch an eclipse while protecting our eyes. And it is easier to handle than a tub of water. To make a pinhole camera, we'll need a thin piece of cardboard, such as the one on the back of a writing tablet, and a sheet of white paper. First, we make a small hole in the center of the piece of cardboard with a large needle or a safety pin. We then hold the cardboard between the Sun and the sheet of white paper. The sun shines through the hole and onto the paper. Look for the image of the Sun on the paper. Then move the cardboard around until the image is clear.

We may see dark spots in the image of the Sun projected onto the piece of paper. Those are sunspots, places where solar flares are occurring. Pinhole cameras are useful for following sunspots as they move across the surface of the Sun as well as for watching eclipses.

at the eclipse would hurt their eyes. Papa and William had a clever plan, however. Using the big tub as a reflecting pool, the family could safely watch the eclipse reflected in the water.

Earlier this morning, as she helped Mama serve breakfast, Caroline had taken a deep breath. Then, she had asked for permission to watch the eclipse with the family. Mama hadn't said no yet, but she hadn't said yes, either. Her mother, like many people at that time, didn't think girls needed to know about comets and eclipses. Girls just needed to know how to cook and clean. But today, Mama was in a good mood. Her oldest son, William, was back home in Germany after seven long years away in England.

When Caroline heard Mama calling her, she sighed, left the window, and hurried up the stairs to finish cleaning. She did not want to make her mother angry today.

Caroline had had a difficult childhood. She was the eighth of ten children born to the unhappy marriage of Anna and Isaac Herschel. Anna and Isaac disagreed about many things. Most importantly for Caroline, they disagreed about education. Isaac was a talented musician and an enthusiastic amateur astronomer who valued education highly. Anna could not read or write.

Worse, she believed educating children simply caused trouble. She grudgingly allowed Isaac to educate their sons, but would not let him teach Caroline more than reading and writing.

Caroline had other strikes against her. At age four, she had survived a bout with smallpox that left her face badly scarred. Then she contracted typhus. The disease limited her growth so that at fourteen, she stood just a bit over four feet tall. As a tiny, unattractive teenager, Caroline thought she probably wouldn't ever marry. Her mother wouldn't let her learn French or any other skill that would help her find work as a governess. Without a husband or some way to support herself, Caroline expected to spend her life working as an unpaid servant for her family.

Even her affectionate father feared for her future. He told her it was unlikely any man would make her an offer of marriage. Perhaps, he added to soften the blow, later in her life some old man might take her for her good qualities. His words dismayed Caroline and made her long for financial independence. Then she wouldn't need an old man for a husband. She could support herself.

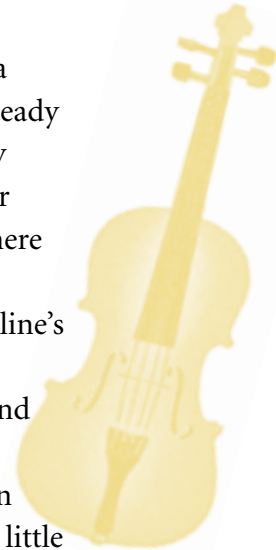
Actually, despite Mama's efforts, Caroline was already a budding musician. Papa gave violin and horn lessons to a steady stream of students. And he often defied his wife and secretly included Caroline in the lessons. What Isaac didn't teach her about music, Caroline absorbed just by living in a house where students were constantly practicing.

Besides her loving father, the other bright spot in Caroline's young life was her oldest brother, William. He shared Isaac Herschel's love of music and enthusiasm for mathematics and astronomy. Papa and William's excited conversations about science and math often lasted far into the night. Mama often yelled at them to quiet down because they were keeping the little ones awake.



Maria Cunitz,

who died fourteen years after Caroline Herschel was born, lived in Poland. She published the astronomical tables based on Kepler's tables. Her volume was published privately in 1650.



600 BCE

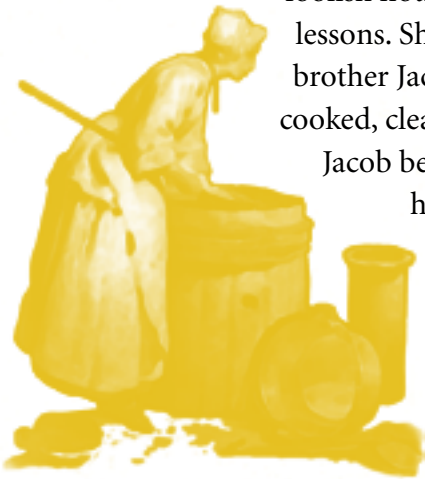
Chinese and Greeks use sundials.

300 BCE

Aristarchus postulates a Sun-centered universe.

William had left for England in 1761, when Caroline was only seven years old. How she had missed him! And now he was home in time for a total eclipse of the Sun. Caroline stopped sweeping as she heard Papa calling the family into the courtyard. Once again she peeked out the window. Mama was there standing next to William. With a smile, Caroline put away her dusting rags and ran to join her family.

Three years later, in 1767, Isaac Herschel died. Seventeen-year-old Caroline was devastated. With Papa gone and William in England, she had no emotional support left. And Mama was more difficult than ever. She seemed determined to stamp out any foolish notions Caroline might have developed from her father's lessons. She ordered Caroline to work as a servant for her brother Jacob, who fancied himself a man about town. Caroline cooked, cleaned, and waited on Jacob and his friends. Sometimes Jacob beat her, calling her slow and clumsy. William, however, had other plans for his sister.



As head musician for a large church in Bath, England, William knew many people in the musical community. He thought Caroline had a future as a professional singer. He wanted her to live with him and study music. For two years, William wrote to his mother trying to persuade her to let Caroline leave Germany. Finally, he agreed to send money home so his mother could hire a servant to replace Caroline. Anna then agreed to let her go. William came to Hanover in August, 1772, to take Caroline to England to live with him and another brother, Alexander.

At twenty-two, Caroline arrived in Bath. She spoke no English and was almost as bewildered and scared as she was excited and happy. She was also determined to earn her own way. She did not want to be a financial burden on William, who had

rescued her from a life of drudgery. She took over management of William's household. It was a big job, but one for which she had lots of practice. She supervised a cook, a maid, and a gardener. She shopped daily for food. At first, shopping was an ordeal. The shopkeepers' rapid English confused her. And she had trouble counting out change with the unfamiliar English coins. Months later, she discovered that her brother Alexander had followed her every day. He kept out of sight. He wanted to be nearby if shopkeepers tried to take advantage of her.

Besides running the household, Caroline helped William with his musical work. She scheduled lessons, rehearsed the choir, and copied arrangements. She practiced piano and voice on her own. It was a busy life, but Caroline was happy, living in England with a much-loved brother and contributing to his success.

Then the day came when Caroline was offered a contract to sing professionally. At last, her musical future seemed assured. Finally, she would be able to support herself. But now she had a difficult choice to make.

William's enthusiasm for astronomy was eating into his time. Every night he gobbled down his dinner. Then he rushed off to study physics or astronomy. When not closeted with books, he designed telescopes. Or he spent hours observing the night sky. Then he started building and selling telescopes as well.

Caroline loved her brother and knew she owed her freedom to him. She also knew he needed her help if he was to have time to study astronomy, carry out his observations, and build bigger and better telescopes. Many years later, she wrote, "My brother would have been very much at a loss but for my assistance." She gave up her chance at a musical career and devoted herself to helping William revolutionize astronomy.

Caroline may have been a tiny person, but she was a dynamo. She loved astronomy and threw herself into telescope



415 CE

Hypatia is murdered in Alexandria.

610 CE

Queen Sondok of Korea builds observatory, Temple of the Moon and Stars



Catherina Elisabetha Koopman was the second wife of amateur astronomer Johannes Hevelius. In this early engraving she is shown making observations with her husband.

building. “I saw almost every room turned into a workshop,” she wrote. “A cabinet maker making tubes and stands of all descriptions in a handsome furnished drawing-room. Alex putting up a huge turning machine in a bedroom for turning patterns, grinding glasses and turning eye-pieces.”

The Herschels set out to transform the science of astronomy. First, they built telescopes that were bigger and better than any the world had known. Then, they used their telescopes to study the night sky in a completely new way. Caroline wrote, “William wanted to study the construction of the heavens. He was not content knowing what other observers had seen.” Caroline became the recorder. As they scanned the sky systematically, she carefully entered all their data in her journals. In 1779, they began an ambitious project. They planned to identify and map every single object they saw in the night sky. In three years, they swept the sky three times. A sweep requires

1050

Astrolabes reach Europe from Egypt.

1098

Hildegard of Bingen is born in Germany.

looking at every portion of the sky and recording the locations and times of appearance of all objects. In their first full sweep, they discovered the planet Uranus, the first new planet to be found in a thousand years.

William taught Caroline physics and math so she could do the calculations and proofread the papers he sent to other astronomers and to the Royal Academy. He called the math problems he designed for her “little lessons for Lina.” By 1780, Caroline spoke two languages and knew astronomy and mathematics. Despite her mother’s efforts to the contrary, she was better educated than most women in Europe.

A critical member of the Herschel team, Carolyn recorded observations and calculated star locations and movements. She compiled all the information into usable tables. She also reorganized the leading star catalog, listing stars by specific zones, based on degrees from the poles, rather than by constellation. In two catalogs, *The Index to the Catalogue of 860 Stars Observed by Flamsteed but Not Included in the British Catalogue*, and *Index to Every Observation of Every Star in the British Catalogue*, Caroline resolved many discrepancies found in earlier publications. She expanded the number of stars included in the catalogs. Then she designed an index that made the catalogs far more useful than they had been.

Using the enormous telescopes the Herschels built, astronomers suddenly found themselves looking at things they couldn’t identify. Some objects appeared as fuzzy blobs. They called these blobs nebulae, from the word “nebulous,” meaning undefined. These nebulae weren’t stars or planets. And their discovery puzzled astronomers everywhere. Caroline’s catalog of 2,600 nebulae ignited



Mary Fairfax Somerville

made a major contribution to astronomy. She translated French mathematician Henri Laplace’s study of celestial mechanics into English. Somerville’s 1813 publication, *The Mechanism of the Heavens*, carefully explained Laplace’s new mathematics to English scientists. The book was a huge success. It established Mary Somerville as a leading astronomer-mathematician of her day. The book was the standard text in the field for a hundred years. Somerville College at Oxford is named for Mary Somerville.

1125

First mention of a mariner’s compass.

1179

Hildegard dies.

What Is a Nebula?

Charles Messier's 1780 catalog listed 103 nebulae, or fuzzy objects. By 1802, Caroline Herschel had added 2600 new nebulae and reorganized the *Messier Catalog*. For another 150 years, astronomers argued about what nebulae might be. The debate was not settled until the 1930s. But the discussions and theories put forth to explain nebulae helped advance our understanding of the universe.

Shown here is the planetary nebula NGC 6369, known to amateur astronomers as the "Little Ghost Nebula," because it looks like a small, ghostly cloud.



a world-wide debate about their identity. The debate advanced astronomy rapidly.

Astronomers were not the only people who wanted the new telescopes. Even George III, the King of England, had to have one. An enthusiastic amateur astronomer himself, King George gave William a small salary as a reward for discovering Uranus. Then the king asked the Herschels to move closer to the castle so they would be handy when he wanted astronomy lessons. The salary let the Herschels give up professional music. They left Bath and turned to full-time astronomy.

Caroline packed up the household and moved it to Windsor. When King George wanted them closer still, she moved again. This time they moved to the tiny town of

Slough, north of Windsor. Here the Herschels turned their house into the foremost astronomical observatory of their time.

Every clear night, Caroline and William studied the heavens. He sat high above the house at a telescope. She sat below in a small, unheated room beside an open window so she could hear him. As William called out the position of each star, comet, or nebula, Caroline checked the star charts and recorded the information. A metronome ticked away at her side, keeping track of the time of passage of each object.

A visitor to the Herschel home wrote in his diary about an evening when the temperature dropped to twelve degrees Fahrenheit. The Herschels just put on more clothes. When Caroline's ink froze, she melted it over her candle and went on writing.

On nights they observed, she worked all night long and slept just a few hours in the early morning. During the day, she copied William's papers for publication and checked his computations. She wrote the directions for assembling the telescopes they sold, and designed and published the star catalogs.

Their telescopes grew larger along with Caroline's catalogs. They made huge polished-metal mirrors to gather and reflect light from distant stars. For their largest, a forty-eight-inch mirror, they melted many pounds of molten metal. They poured the liquid metal into a mold formed in a huge mound of soil and sand in the backyard. After casting, they polished the mirrors to a high gloss by hand. William polished the mirror for days at a



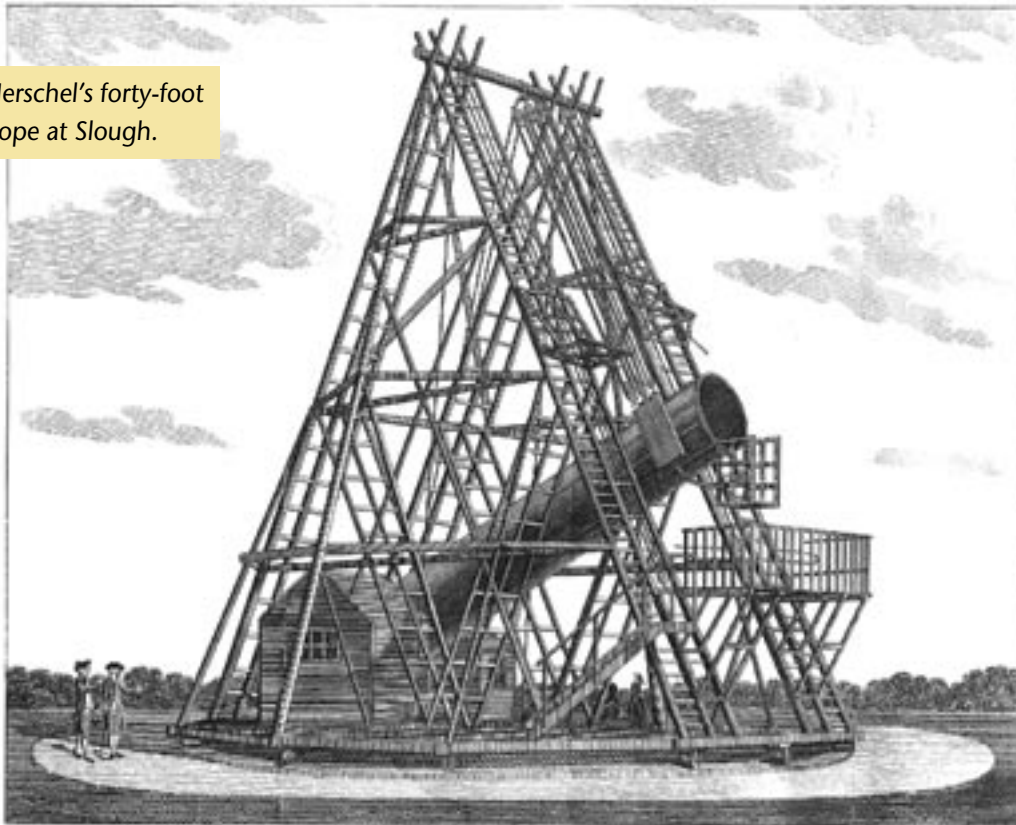
The Ant Nebula was discovered in 1922. The strange shape of this nebula intrigues astronomers. The unusual length of the nebula—over a light-year long—and the 1000-kilometer-per-second speed with which gas is expelled from the central star, may be clues to the shape.

time, and Caroline spooned food into his mouth as he worked.

When they mounted the big mirror in a forty-foot-long tube, it became the largest telescope in the world. It was often called the eighth wonder of the world, and travelers came to Slough from all over the world to see it.

As William and Caroline's reputations grew, astronomers from around the world visited the Herschel home to exchange ideas and information. William also visited other astronomers, both in England and Europe. Caroline enjoyed meeting and talking with visiting scientists in her own home, but she hated

The Herschel's forty-foot telescope at Slough.



View of Dr. Herschel's Forty Foot Telescope.

1750

Caroline Herschel is born in Germany.

1771

Caroline goes to Bath, England, to live with her brother William.

Fear of Comets

Our ancestors were afraid of comets because they appeared with no warning and no explanation. They seemed like dreadful omens, and people easily associated them with catastrophes such as plagues and earthquakes. People often blamed the death of a king or emperor on the appearance of a comet. Sometimes, the death and the comet were separated by months or even years. But that did not keep people from believing that comets were omens.

When English astronomer Edmund Halley studied the historic records of comet appearances, he noticed that the descriptions of one particular comet, seen in 1531, 1607, and 1682, seemed quite similar. He suggested that all three of these sightings were of the same comet. Then he went even further. He calculated the orbit of this comet and predicted its next visit to earth. When his prediction came true, the comet was named for him. Halley's Comet is due for a return visit in 2062.



German astronomer Peter Apian observed that the tail of a comet always points away from the Sun.

As more comets returned as predicted, they began to lose their mystic importance. People thought of them as natural occurrences. Few people now believe comets foretell the death of powerful people or bring plagues. However, comets may cause catastrophe if they hit the Earth. In 1994, Carolyn Shoemaker watched as comet Shoemaker-Levy slammed into the planet Jupiter (see page 138).

Late in 1998, scientists found an impact crater that included pieces of glass that appeared to have come from a comet crashing into the Earth. Some scientists think this kind of impact killed off all the dinosaurs millions of years ago. Astronomers who worry about comets hitting the Earth have started programs to spot them as early as possible (see page 141).



Maria Margarethe Kirch and Christine Kirch

were the wife and daughter of Gottfried Kirch, who headed the Berlin Observatory in the early 18th century. While her husband was alive, Maria helped with his observations. After his death, Maria worked at other observatories. When their son became an observer at Berlin in 1716, she and Christine worked as his assistants, doing observations and calculations.

travel and seldom left Slough. She had little patience with tourists who came to see the sights without any interest in astronomy, even members of the royal court. In her diary, she referred to one lady-in-waiting as a “giggling ninny.”

Caroline’s life settled into a peaceful routine. But William had another surprise for her. In 1788, he married Mary Pitt, a widow who lived nearby. The marriage came as a shock to Caroline. Another woman now held first place in William’s affections, and Caroline worried again about money. Where would she live? What would she eat? How could she clothe herself?

William solved Caroline’s money concerns by persuading King George to give her a personal salary. Finally, in 1787, at the age of thirty-four, Caroline Herschel was financially independent. But she had become emotionally estranged from her brother.

Fortunately, William’s new wife, Mary, was a warm, friendly woman who must have understood Caroline’s feelings. Her kindness toward Caroline began to mend the rift caused by the marriage. And the birth of baby John helped. Caroline adored her nephew and delighted in helping him grow up to become an astronomer nearly as well known as his father.

Caroline’s Comet

When William traveled to Europe, Caroline scanned the night sky alone, sweeping for comets. In 1786, she spotted an object she knew had not been there the night before. “The object of last night *is a comet*,” she wrote in her diary on August 2, 1786. With that note, she became the first woman in recorded history to discover a comet. She eventually discovered numerous nebulae and a total of nine comets, though not one was named for her.

1786

Caroline Herschel discovers her first comet. The Herschels move to Slough, England.

You, Too, Could Discover a Comet

Looking for a comet is called comet sweeping. Astronomers know that comets often come out of certain areas of space. They check these sections of the sky every night. Astronomers are so familiar with the stars in these areas that they immediately recognize when a new object appears.

Comet sweepers look for rapidly moving, fuzzy objects. Comets are closer than stars and move very fast. Their positions seem to change rapidly, often in just a night or two.

The eighteenth century astronomer Charles Messier published a catalog of more than one hundred fuzzy objects observable with a small telescope. As it turned out, Messier's fuzzy objects are not comets.

But comet sweepers have to eliminate known nebulae from consideration. If we're going to hunt comets, we need a copy of Messier's catalog. Then, we use the telescope to locate each of Messier's fuzzies, and memorize its location. Once we're familiar with those common fuzzy objects, we're ready to hunt.

Comets are easier to see if they are close to the Sun. We begin a sweep by aiming the telescope at an area close to where the Sun went down. Then we scan a small area at a time, looking for fuzzy objects. If we find a fuzzy that we know is not in Messier's catalog, we'll check a star atlas and see if it identifies our fuzzy. If the object is not in current catalogs, it may be a comet.

Astronomers who think they have discovered a comet should contact the Central Bureau for Astronomical Telegrams.



On January 30, 1996, using binoculars, Yuji Hyakutake discovered the brightest comet to visit the Earth in twenty years (top). Exactly one year later, Comet Hale-Bopp lit up the night sky (bottom). Thomas Bopp, Arizona, and Alan Hale, New Mexico, discovered the comet, the farthest one ever discovered by amateurs.

1787

King George III gives Caroline Herschel a salary. William Herschel marries Mary Pitt.

“Letter from Caroline Herschel (1750-1848)”

A Poem by Siv Cedering

(In this poem the poet imagines herself as Caroline Herschel)

William is away, and I am minding
the heavens. I have discovered
eight new comets and three nebulae
never before seen by man,
and I am preparing an Index to
Flamsteed’s observations, together with
a catalog of 560 stars omitted from
the British Catalog, plus a list of errata
in that publication. William says
I have a way with numbers, so I handle
the necessary reductions and
calculations. I also plan
every night’s observation
schedule, for he says my intuition
helps me turn the telescope to discover
star cluster after star cluster.

I have helped him polish the mirrors
and lenses of our new telescope. It is
the largest in existence. Can you imagine
the thrill of turning it to some new
corner of the heavens to see
something never before seen
from earth? I actually like

that he is busy with the Royal Society
and his club, for when I finish my other work
I can spend all night sweeping
the heavens.

Sometimes when I am alone
in the dark, and the universe reveals
yet another secret, I say the names
of my long, lost sisters, forgotten
in the books that record
our science—

Aganice of Thessaly,
Hypatia,
Hildegard,
Catherina Hevelius,
Maria Agnesi

—as if the stars themselves could remember.
Did you know that Hildegard
proposed a heliocentric universe
300 years before Copernicus? That she
wrote of universal gravitation 500 years
before Newton? But who would listen
to her? She was just a nun, a woman.
What is our age, if that age was dark?

1818

Maria Mitchell is born in Nantucket.

1823

Caroline Herschel returns to Germany after William’s death.

As for my name, it will also be forgotten, but I am not accused of being a sorceress, like Aganice, and the Christians do not threaten to drag me to church, to murder me, like they did Hypatia of Alexandria, the eloquent young woman who devised the instruments used to accurately measure the position and motion of heavenly bodies. However long we live, life is short, so I work. And however important man becomes he is nothing compared to the stars. There are secrets, dear sister, and it is for us to reveal them. Your name, like mine, is a song. Write soon.

Caroline

When William died in 1822, Caroline returned to Hanover to live with her younger brother Dietrich. She was now the foremost woman astronomer in Europe. Astronomers from all over visited her. The King of Prussia awarded her the Gold Medal of Science. And in 1835, when she was eighty-two, the Royal Astronomical Society of England elected her to honorary membership. Honor and recognition had finally come to Caroline Herschel, along with her independence. The unpaid household servant had become the First Lady of Comets. ●

Caroline Herschel shown at age 97 in Hanover, Germany, in an engraving by George Muller.



1835

Caroline Herschel is elected to the Royal Astronomical Society of England.

