An Unusual Orbit: The Life and Discoveries of Carolyn Shoemaker

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Briley Lewis, Graduate Student, UCLA Department of Physics and Astronomy

blewis@astro.ucla.edu

"To work in planetary science is to work in an area that takes us both back to the origin of our solar system and beyond it into the future."[1] *— Carolyn Shoemaker*

Carolyn Shoemaker (Credits: USGS Astrogeology[2])

Not everything in our solar system follows a tidy, near-circular orbit, and not every scientist follows a typical, traditional path. Carolyn Shoemaker was unexpectedly pulled into science at nearly age 50, and despite her lack of scientific background, she went on to change our understanding of the solar system by discovering over 800 asteroids and comets, including the famous Shoemaker-Levy 9.[1,2] Along with her husband and scientific partner, Gene, she held a particular interest in asteroids with strange planet-crossing orbits, since their impacts have huge implications for life on Earth.[1] Shoemaker recently passed away at the age of 92 in August 2021, leaving behind a legacy of science built on community and collaboration.[12]

Shoemaker's First Education

Carolyn Shoemaker never meant to be a scientist. Neither of her parents were scientists, and her science classes bored her.[1,2] Attending college right after the end of World War II, her goal

was purely pragmatic: to get out as quickly as she could and get on with her life. At her hometown college of California State University, Chico, she earned a master's in history, a master's in political science, and a high school teaching credential.[1]

Her first degrees weren't totally unrelated to her later pursuits, though. Shoemaker explained, "These fields are basically historical sciences—astronomy is like a time machine that tells us about the creation of our solar system and our universe, geology reveals the nature of our world in the past and helps us to understand Earth and its neighboring planets today."[3]

After graduation, Shoemaker planned to teach 7th grade in Petaluma, California.[1] Until she met Gene, that is.

A Nourishing Partnership

As Shoemaker herself says, it's hard to talk about her career in science without talking about her beloved husband, Eugene (Gene) Shoemaker.[3] Married in 1951, Gene was a geologist working for the U.S. Geological Survey (USGS) with an infectious love of science. He brought Carolyn along on mapping expeditions, without any reservations about the lack of women in field work at the time, and enthusiastically taught her about rock structures and sedimentary layers. She soon became pregnant with their first child, and although she couldn't join for the strenuous field work, she kept camp and learned from all the fireside stories told by the scientists.[1]

The launch of Sputnik in 1957 changed their course, though—Gene's dream of science on the Moon felt suddenly within reach. He began to lobby for an astrogeology branch of the USGS, travelling all across the country for work. Carolyn stayed at home in California to care for their young kids, eagerly awaiting updates from Gene when he returned home.

Eventually, the family settled at Caltech in Pasadena for Gene to work on the Apollo and Voyager missions. Gene soon started the first search for asteroids that cross Earth's path, known as Near Earth Objects (NEOs), at Palomar Observatory near San Diego. An enthusiastic supporter of women working in astronomy, he worked with Eleanor (Glo) Helin, a female trailblazer in asteroid science. Although science classes never caught Carolyn's attention, the electric enjoyment of science by Gene's colleagues did. Caltech really amazed her—this was where she "fell in love with planetary science, the skies, our solar system, and the universe."[1]

Carolyn had years of experience listening to cutting edge research, immersed in the community with her husband. When her kids left home in the 1970s, science was a natural choice for what she should do next and Gene offered for her to work with him on his asteroid research. Other astronomers helped train her, and she began searching through data for new asteroids and helping with observations at Palomar.[1,3]

Fellow planetary scientist Mary Chapman commented on this partnership that "the two mutually supported each other throughout their symbiotic marriage. Without Gene, Carolyn would never

have become a famous astronomer. Without Carolyn's help, Gene would never have progressed very far with his asteroid statistics program, found comet Shoemaker-Levy 9, and probably would never have mapped impact craters in Australia. Without each other, they would not have been successful companions and working partners, had their children, or home life."[2]

Identifying Minor Planets (on Film)

The Shoemakers' 1980s asteroid searches, like the Palomar Asteroid and Comet Survey they started together, used film for their telescope observations. Film was a tricky medium—it had to be kept in the dark, hypersensitized to shorten exposures, and cut to make round pieces. In order to find moving small solar system bodies, they used spectrographic film and placed it within a stereomicroscope, which made the moving bodies appear to float, distinguishing them from background stars.[1] This work could be quite tedious and grueling, with a typical night of work lasting 13 hours with no rest, quickly changing out and developing films at the telescope.[1,3] It took a keen eye, great patience, and attention to detail to do this kind of work, all of which Carolyn had.[3]

Gene's method of science was to collect as much data as possible, and deal with the analysis later.[5,6] They spent a week each month, when the Moon was dark, collecting around 100 films per night on the 18 inch Schmidt telescope, Palomar's oldest and smallest.[1,6] They were able to cover a whopping 60 square degrees of sky—around 300 times the angular size of the Moon—on a 6 inch film.

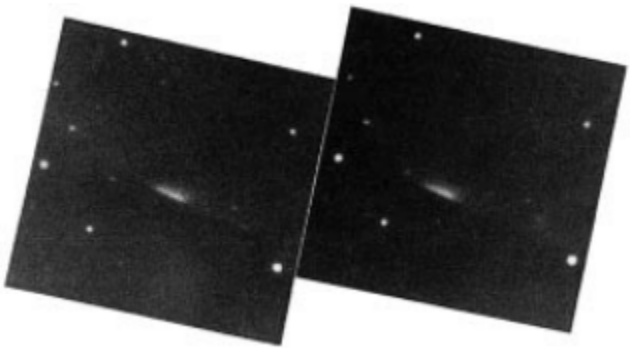
A true team effort, they recorded over 2,000 new asteroids. As Carolyn recalled, "The excitement of a special discovery was a reward for the whole team, because it took each of us working together to make those discoveries. Throughout the years we never ceased to be intrigued and elated when we found an unusual object."

In true Gene Shoemaker fashion, only around 270 of those have official number designations, and thousands still need further observations to determine their orbits. The Shoemakers used their observations to estimate the number of Earth-crossing asteroids larger than 20 kilometers in diameter (around 1500), and to estimate that Earth will see two impact craters larger than 20 kilometers every million years. 60 percent of these asteroids also crossed Venus's orbit, meaning that Venus should have a cratering rate fairly similar to Earth's, another similarity between these sister planets.[6]

They also found almost 200 asteroids with high inclination orbits, many comets, and the first Trojan asteroid, trailing Jupiter in its orbit. They appropriately named it Paris, for the Greek mythological antagonist of the Trojan war.[6] Asteroids and comets, the leftover junk of our solar system's formation, hold so many clues to how our planets came to be. Gene and Carolyn did the hard, tedious work of discovering and cataloguing these asteroids, giving us the first glimpse into exactly what is out there tumbling around near our planet. By far their most well known discovery, though, was a happy accident at Palomar, taken on a night where they almost gave up.[8]

Comet Shoemaker-Levy 9

Observing the night sky requires some cooperation on the part of the sky. Wind, clouds, and a number of other natural factors can ruin a night's time on a telescope. One night during their survey at Palomar, there were terrible winds, patchy clouds obscuring the stars, and to make it worse, someone had ruined a large cache of the photographic films. Usually, the team would have quit to avoid wasting expensive film, but instead they continued and used some of the slightly damaged film since it was already a loss. With Gene holding the telescope's shutters open against the wind, they took the first images of the famous Shoemaker-Levy 9 (SL-9) comet that night.[6,8,10]



Carolyn's view of SL-9. (Credits: Eugene and Carolyn Shoemaker, David Levy[10])

"I don't know what this is, but it looks like a squashed comet," Carolyn said, as she noticed SL-9 on the films.[10] Further research showed that this unique comet was actually a series of 21 broken up pieces, all in orbit around and on a collision course with Jupiter.[9,10] These fragments were expected to hit only a year later in summer 1994, crashing into Jupiter with an energy equivalent to two million of the largest nuclear bomb ever dropped (the 50 megaton Russian Tsar Bomba).[9]

SL-9 was the first comet to be seen in orbit around a planet, the first comet to be seen completely disrupted, and the first large object to be seen impacting a planet. Astronomers were eager to observe the impact—would the atmosphere swallow the comet whole, or would it disrupt the atmosphere, maybe even leaving a lasting impression?[10] Carolyn called it "everyone's comet" due to the incredible interest from professional and amateur astronomers, as well as the general public.[3] It's clear that she saw the value of this comet's discovery in not only the scientific knowledge that it would provide, but also the public excitement around science and the increased cooperation between various people and institutions it generated.[3]

The first Hubble Space Telescope images of the collision were soon revealed, and everyone was thrilled by the results. Plumes from SL-9's impact were clearly visible, rising 3000 kilometers above the surface of Jupiter.[8] For reference, the International Space Station is only around 400 kilometers from Earth's surface. Impact scars lasted for years, with dark marks from

the comet's material propagating across the atmosphere, allowing researchers to trace Jupiter's wind patterns.[6]

Carolyn connected this once-in-a-lifetime event with her research on impacts on our own planet, explaining that we were lucky it was Jupiter being hit and not Earth. On our own planet, an impact of that size would have cometary material throughout our sky, blotting out the sunlight—similar to the event that killed the dinosaurs.[6]

Craters Across the World

In addition to their work on otherworldly impactors, the Shoemakers recorded detailed maps of impacts here on Earth, particularly in Australia. Australia is well-suited for crater studies, with its flat, dry terrain. Gene and Carolyn visited over 20 different impact structures, fastidiously mapping these craters and investigating their structures. They traveled alone, with no GPS or satellite, finding new features to add to the Australian impact record. This record, Gene hoped, would help determine the flux of impacting asteroids on the ancient Earth.[5] This work illustrated that planetary science isn't just an endeavor for space missions; craters here on Earth are ready for investigation, excellent sites to see the science of impacts up close.[5]

Gene and Carolyn also took opportunities to engage with the local community, finding craters by word of mouth and local legends, even occasionally following an Aboriginal guide. At Liverpool crater, Carolyn and their guide Johnny Maurirundjul exchanged stories about the crater's origin, which in Aboriginal culture is the nest of a giant catfish.[5]

Australia, however, is where the Shoemaker's partnership came to an abrupt end. Gene was killed in a car crash in 1997 on one of their excursions, leaving Carolyn injured and much of this data unanalyzed and unpublished.[1]

Legacy and Lasting Impacts

Carolyn Shoemaker spent the later years of her life studying Near-Earth Objects and watching the field of planetary science grow and thrive.[12] Even after her husband's death, she remained engaged in astronomy, striving to finish some of the work they had started together.

Astronomy relies on the hard work of cataloguing the sky, and the Shoemakers' work essentially founded the scientific studies of impact craters and planet-crossing asteroids. "Carolyn's legacy is as part of the Shoemaker team," explains Dave Jewitt, UCLA Professor of Astronomy and famous dwarf planet discoverer. "It takes two or more people to operate [the telescope] and develop the plates, so Carolyn was essential and she was obviously totally invested."[11]

Among other honors, she was awarded an honorary doctorate from Northern Arizona University in 1990, finally earning a degree to match her experience and contributions. There is even an asteroid named in her honor, 4446 Carolyn.[12]

Conclusion

“Without the human relationships we cherish, knowledge would count for naught; both are to be nourished,” said Shoemaker. “Henceforth, I'll continue my scientific exploration, knowing that I must not neglect the other side of living.”[1]

Carolyn Shoemaker engaged in astronomy with her whole self—her identity and experience as a woman, a mother, a wife, a friend, a curious learner, and a scientist. Her story illustrates how becoming a successful scientist depends not only on the work you do, but who you do it with and who teaches you along the way. “Successful careers—such as Carolyn's—depend on the individual and on their luck in being influenced by other people,” explained Mary G. Chapman, senior scientist at the Planetary Science Institute.[2] Throughout her career, a repeated theme in Shoemaker’s comments is how her collaborators made all the work she did possible, worthwhile, and enjoyable.

Shoemaker also reminds us that the value of science often lies in how it relates to our communities, to the livelihoods of the unique life forms here on Earth. Asteroids are not simply distant rocks in space, and astronomy is not an impractical endeavor. Instead, she asserted that “impact cratering is a process that affects all life, which means to me that science and society cannot help but be intertwined...as one progresses, so does the other. Pure science, the search for knowledge without knowing where it will lead, is part and parcel of what will make the world a better place for all mankind.”[3]

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About the Author

Briley Lewis is a fourth-year graduate student and NSF Fellow at the University of California, Los Angeles studying Astronomy & Astrophysics. Her research focuses on how we can apply techniques from direct imaging of exoplanets to other planetary science questions. She is a member of the Astrobites collaboration, contributing author for Massive Science, and former organizer for ComSciCon-Los Angeles. She also teaches writing at UCLA in her course for first year undergraduates, “Astrobiology in Science Journalism.” Follow her on Twitter @briles_34 or visit her website www.briley-lewis.com.