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Memorial

Alastair Graham Walter Cameron (1925–2005)

Alastair Graham Walter Cameron (1925–2005), winner of the Meteoritical Society's Leonard Medal in 1994, died of heart failure in Tucson, Arizona, on October 3, 2005. Once described by historian of science Stephen Brush as "the most influential North American theorist" in planetary sciences of his generation, Cameron was a founder of modern planetary astrophysics. His work included developing the s-process, the r-process, and statistical equilibrium models for nucleosynthesis, providing elemental abundances and the first numerical models for the physics of the solar nebula, and developing the now widely accepted "giant impact" hypothesis for the origin of the Moon. But he is also remembered as an invigorating and delightful colleague whose sharp mind was tempered with a wry sense of humor.

Cameron was born in Winnipeg, Manitoba, on June 21, 1925. In an autobiographical essay published in the 1999 *Annual Review of Astronomy and Astrophysics*, he described some of his more colorful ancestors, including a grandfather who came to Manitoba as an Indian fighter but later worked with the Indians hunting food for the construction crews building the Canadian Pacific Railroad. His father was a chemist who eventually headed the biochemistry department at the Manitoba Medical College, a branch of the University of Manitoba. Raised in an academic household, he relates, "I was told that around the age of four I addressed all men as 'doctor,' clearly an early attempt at forming a hypothesis based upon limited data."

At Al's memorial service in Tucson, his niece Valerie Lemieux and her husband Ron recounted other family stories from Al's youth. After Al's mother separated from his father, she raised Al by herself. He attended Ravenscourt High School, a prestigious private school in Winnepeg, but he was an indigent student who had to work his way through school. As a teenager, he was the class bookie for student betting on horse races and did quite well for himself. Around 1941, he made a bet with a classmate, for $25 or so, that man would land on the Moon by 1970. Years later, when the classmate paid him the money, he asked Al how he knew this would happen. Al said that he computed the rate at which man was moving faster and faster—horse and buggy, train, car, plane—and extrapolated this to the point where we should be able to move fast enough to have space travel by 1970! (He never cashed the check, but kept it framed on his wall.)

In his youth, he was a great fan of fantasy and science fiction. Active in Canadian science-fiction fandom in the late 1940s and early 1950s, he developed a Fantasy Classification System published by the Canadian Science Fiction Association in 1952 (when one of us worked as a post-doc for him in the late 1970s, we learned from his wife Betsy that he was still an avid fan of the Doc Smith Lensmen novels, which he would re-read regularly!).

Cameron studied physics and mathematics at the University of Manitoba and earned his Ph.D. in nuclear physics at the University of Saskatchewan studying photonuclear reactions under Leon Katz. Upon graduation in 1952, he took a position at Iowa State College (now University), in Ames, Iowa, working at the Ames Laboratory of the U.S. Atomic Energy Commission. While browsing through an issue of *Science News Letter* (now *Science News*), he first saw a report that Mount Wilson Observatory astronomer Paul Merrill had observed the lines of the unstable element technetium in red giant stars. Cameron related: "That moment marked an instant turning point in my career. . . . I bought all the graduate-level astrophysics texts I could find, subscribed to *The Astrophysical Journal*, and started some intense reading."

By 1954, he was devoting all of his energies to exploring the astrophysical settings of nuclear physics, and he moved back to Canada to work for the Canadian Atomic Energy Project at Chalk River, Ontario. Here he first developed his numerical models for equilibrium burning and the s-process inside stars. He also formed a lifelong attachment to ever-faster computers, a passion that he kept to the end of his life.

Another lifelong attachment was formed in 1955 with his marriage to Elizabeth ("Betsy") MacMillan, a partner who shared his sense of humor and passion for hard work until her death in 2001.

At Chalk River, Cameron recognized that his nucleosynthesis models could be tested by comparing his computed elemental abundances against the observed abundances of the elements in nature. The original Suess-Urey cosmic abundances, published at this time, were a combination of solar, stellar, and meteoritic measurements; Al soon realized that his s-process models could be used to align the data from these different sources and interpolate abundances for the rarer elements. Eventually, he produced his own tables of abundances, which he refined over the next twenty years. They served the astrophysical community as the standard for cosmic abundances until the late 1980s.

But understanding elemental abundances based on data from meteorites meant understanding meteorites: their classes, compositions, inclusions, ages, and origins. This in turn lead Cameron to ponder the environment where these meteorites were formed. In 1959, he spent a sabbatical year at Caltech; while he was there, among other projects, he worked with Fritz Zwicky on the then-controversial idea of neutron stars. This led him to consider the physics of what is now known as r-process nucleosynthesis in the late stages of a star's life. John Reynold's discovery of evidence in meteorites for the extinct radionuclide ^{129}I, announced while Cameron was at Caltech, tied Al's nucleosynthesis work to models for understanding how short-lived nuclides—the products of supernovae nucleosythesis—could be incorporated into solar system objects. His first numerical models for the solar nebula followed.

To provide greater support for his burgeoning interests in astrophysics, Cameron left Chalk River in 1961 for the newly formed Goddard Institute for Space Physics in New York City. Soon he was directing the research of graduate students from Columbia University, New York University, the Graduate School of Science at Yeshiva University, and Yale—among the latter, Dave Arnett, Carl Hansen, and Jim Truran. In 1965, he accepted a teaching position at Yeshiva, which was seeking to expand its graduate physics program; when that program foundered, he accepted an appointment at Harvard in 1972 and assumed the role of associate director for planetary sciences (and later, of theoretical astrophysics) at the Harvard-Smithsonian Center for Astrophysics. By 1976, he was chairman of the astronomy department at Harvard.

At this time, he began to develop his ideas on the origin of the Moon. As he described to Ursula Marvin (in an oral history published in *Meteoritics & Planetary Science* in 2002), he had been thinking about a giant impact origin when he heard Bill Hartmann present a similar idea at the 1974 Planetary Satellites meeting in Cornell. "As soon as he finished, my hand went up in the audience," Al said. "Bill has said that he was quaking a bit thinking, 'Oh, gee, now am I going to get shot down for good?' Instead of that, I agreed with him and told him the impacting body would have to have been at least the mass of Mars. Bill hadn't considered . . . the angular momentum." In 1976, Cameron published the first of a number of papers outlining his physical model for the Moon, work that continued for 25 years with a number of co-authors.

While always maintaining an exhausting publication record, this period also saw Cameron take on an important role in the administration of "big science." Among other activities, he became a member of the U.S. National Academy of Sciences (he became a U.S. citizen in the 1960s) and served on its advisory boards, was active in COMPLEX and its governing body, the Space Science Board (which he chaired for two terms in the 1970s), and in 1991 he helped organize the first Gordon Conference on Origins of Solar Systems, which continue to this day. With both his scientific output and his important administrative roles, he was for thirty years arguably one of the most influential planetary scientists in the world.

However, even more remarkable was how Cameron managed to achieve all these things while maintaining a personal integrity marked by loyalty, grace, and honor. Al Cameron had tremendous intellect and power. But he used these to enhance the science he was exploring, the students, post-doctoral fellows, and colleagues in his midst, and the institutions, like Harvard, that he served. His sense of fair play was matched by his willingness to support and defend those who worked under his direction. And he remained a good and loyal friend whose support continued long after one had worked with him.

Famously, he was one who was always willing to change his theories in light of new data, a tendency that often kept the rest of the field out of breath trying to keep up. But throughout his career he also kept his wry sense of humor. When he introduced his giant impact theory at the annual Lunar and Planetary Science Conference in the mid-1970s, he noted that his diagram of material flowing off the Earth resembled Al Capp's cartoon character, the Schmoo, which he said was appropriate because the Schmoo, like his theory, was famous for being relatively formless but able to give you "anything you wanted!"

In his *Annual Reviews of Astronomy and Astrophysics* article on the occasion of his retirement in 1999, Cameron reflected on his work, saying, "The core of my intellectual approach to trying to understand the universe is to seek consistency everywhere. . . . But I have a reputation for frequently changing my mind and that is caused by the constant search for consistency. I am counting on that to sustain me and keep me mentally alive as I head toward retirement . . . I want to keep the computers running as I try to resolve yet another inconsistency, as long as I am physically able to do so." He did so, admirably.

Upon retirement he moved to Tucson, joining the newly formed Academic Village for retired academics and scholars.

Al spent a lot of time on Academy Village business; he also donated old computers to the Village and instituted a series of computer classes. He put a lot of thought into designing his home and several of his ideas were adopted by other residents. He actively promoted high-speed Internet access, first via satellite and later via land lines, and instituted regular discussion groups for village residents.

In retirement, he maintained an office (filled with computers) at the Lunar and Planetary Laboratory of the University of Arizona. His final collaborator, Katharina Lodders of Washington University, recalls, “Al kept up an amazing pace of going through large amounts of material and writing out his thoughts in long email messages and paper drafts. The last manuscripts that Al had sent me were quite compact and full of new thoughts that Al developed. . . . I thought that Al was several light-years ahead in his manuscripts, moving from meteoritics and the solar system deep into the galaxy. . . . At the time, I thought that much more work was needed to fully explore the many ideas that Al placed into these manuscripts. But maybe Al knew somehow that he would be leaving us soon and felt rushed to put down on paper whatever he could.”

In addition to the Leonard Medal, Al Cameron was also the recipient of the 1983 NASA Distinguished Public Service Medal, the 1988 J. Lawrence Smith Medal from the National Academy of Sciences, the 1989 Harry H. Hess Medal from the American Geophysical Union, and the 1997 Russell Lecturer Prize from the American Astronomical Society. In addition to his NAS honors, he was a Fellow of the American Academy of Arts and Sciences, the Royal Society of Canada, the American Association for the Advancement of Science, the Meteoritical Society, and the American Geophysical Union. Most recently, the Division of Nuclear Physics of the American Physical Society named Cameron the 2006 recipient of the Hans A. Bethe Prize for for his “pioneering work in developing the fundamental concepts of nuclear astrophysics.” He learned of this final honor five days before his death.

Guy Consolmagno SJ
Specola Vaticana
Bruce Fegley
Washington University
David Kring
The University of Arizona