

At a Meeting of the Faculty of Arts and Sciences on May 19, 2009, the following Minute was placed upon the records.

ALASTAIR GRAHAM WALTER CAMERON

Born: June 21, 1925
Died: October 3, 2005

Alastair Graham Walter Cameron was born in Winnipeg on June 21, 1925, and died in Tucson on October 3, 2005. As a boy his interests ran to science fiction and away from sports. His father was head of the biochemistry department at the Manitoba Medical College; at the age of four Cameron addressed all men as "Doctor," which he later said was an early example of forming a hypothesis based on limited data.

His mother raised him by herself. Working his way through a private high school he became a bookie, taking bets from fellow students, and did quite well. In about 1941 he made a bet with a classmate that man would land on the Moon by the year 1970. Years later the classmate asked Cameron how he had known when the Apollo Program would take place. He replied that he had extrapolated the speed of transportation to the time when that speed would exceed that needed to escape from the Earth.

He majored in math and physics at the University of Manitoba, and for his physics Ph.D. at the University of Saskatchewan, where he devised a new method to determine nuclear cross sections. He went on to apply nuclear physics to the origin of the chemical elements, or nucleosynthesis, in stars. In 1955 he married Elizabeth "Betsy" MacMillan. Betsy called Cameron "Alastair," but in the scientific community he was known only as "Al."

After the Ph.D., Cameron spent two years at the Ames Research Center of the U.S. Atomic Energy Commission. While there he read that the astronomer Paul Merrill had observed a feature in the spectrum of a red giant star that corresponds to the chemical element technetium (Tc). Technetium has no stable isotopes; it was discovered in 1937 only after bombarding molybdenum with energetic particles; hence its name, derived from the Greek for "artificial." Given the fact that technetium decays rapidly into other elements, Cameron reasoned that it must have been created in the star where Merrill found it. Cameron found this discovery "very exciting" because it provides a clue to the origin of the heavy elements in the Universe. Having never studied astrophysics before, Cameron immersed himself in the literature. In 1954 he relocated to the Chalk River Laboratory of the Canadian Atomic Energy Project, where he calculated cross sections for the many nuclear reactions that occur in the interiors of stars when the temperature is high enough for collisions between charged nuclei to overcome the electrical repulsion between them.

The temperature at the center of the Sun is 14 million degrees, high enough to allow the conversion of hydrogen into helium, but not high enough for the reactions that ultimately lead to the creation of elements as heavy as Tc, that require hundreds of millions of degrees.

While Cameron was working on nucleosynthesis, other theorists calculated that the Sun would run out of hydrogen in 5 billion years, at which time the temperature in its core would begin to rise, and the Sun would become a red giant star of the type that Merrill observed to contain Tc. Surprisingly, when stars run out of one nuclear fuel, their cores get hotter, not cooler, and then new fuels that react only at higher temperatures kick in. In red giant stars the helium produced earlier is reacting to form even heavier elements.

Cameron predicted what elements are produced and in what quantities. He found that indeed technetium is produced along the way, explaining Merrill's observation. In order to be found in the atmospheres of the Sun and other stars, and in solid bodies such as planets and meteorites, new elements have to first be ejected from the parent star into space where they contaminate interstellar matter destined to form new generations of stars and planets. Thus the full understanding of nucleosynthesis involves the formation of stars and planets, as well as the ejection of heavy elements into space by red-giant winds and supernova explosions. Undaunted by the challenge, Cameron plunged into a full range of theoretical astrophysics.

Cameron published his papers on nucleosynthesis in 1957. Experts attribute the birth of the field of nuclear astrophysics to those papers, together with one by a group at Caltech led by William Fowler published the same year. Fowler, an experimentalist, won the Nobel Prize in 1983 for his work in the field, and in his Nobel Lecture credited the independent work of Cameron.

In 1961 Cameron moved from Chalk River to the newly formed Goddard Institute for Space Studies in New York City. There he supervised graduate students at Columbia, New York University, and Yale. He taught regularly at Yale, where his students compiled his notes into a monograph that is highly regarded, but unfortunately, was never published. In 1973, upon the founding of the Harvard-Smithsonian Center for Astrophysics (CfA) at 60 Garden Street, Cameron was appointed to a professorship in the Department of Astronomy at Harvard. He also accepted a position as associate director of CfA for Planetary Science, a field to which his interests were increasingly turning because of the continuing discoveries of anomalous abundances of isotopes in meteorites. His model of the Solar Nebula, a disk of gas and dust formed at the time of the origin of the Sun 4.5 billion years ago, provides quantitative temperatures that theorists use in their studies of planet formation.

During this period, Cameron is reported to have given a seminar at Caltech covering the entire history of the Sun and planets, from the collapse of an interstellar cloud to the coagulation of dust to form the solid cores of the planets. When asked what he did on the seventh day, Cameron replied, "I rested."

An important result of Cameron's work was his conclusion that the main product of the buildup of the observed high abundance of the elements near iron in the periodic table is not iron per se, as had been assumed, but radioactive nickel 56. His idea was verified many years later by a NASA spacecraft.

In 1982 Cameron became the chair of the Space Science Board of the National Academy of Sciences, which advises NASA on its science program, and at Harvard he served six years as chair of the Department of Astronomy. During this period he also organized annual conferences to bring together astrophysicists and planetary scientists to enhance collaborations between their different specialties.

He then decided to attack a long-standing theoretical problem in planetary physics: the origin of the Moon. The Apollo Program had found that unlike the Earth, the Moon has no iron core, but is composed solely of the same material as the mantle of the Earth. At the time theorists could not explain this fact. Cameron proposed that the Moon formed from a disk of debris orbiting the Earth, much as the Solar Nebula orbited the Sun. But where could the debris have come from? Cameron proposed that it was material ejected from Earth's mantle when a Mars-sized body collided with the Earth early in the history of the solar system. That would explain the Moon's composition, but how would the debris reach the distance of the Moon? Cameron attacked this problem head on, acquiring faster computers for his office in order to model the collision event. He finally succeeded in showing that such a collision would result in a disk of the correct mass, as well as the angular momenta of the

Earth and Moon that are observed today. Cameron's theory is now the accepted one for the origin of the Moon.

Cameron received honors from many scientific societies, among them the Petrie Prize of the Canadian Astronomical Society, the NASA Distinguished Service Medal, the Smith Medal of the National Academy of Sciences, the Hess Medal of the American Geophysical Union, the Leonard Medal of the Meteoritical Society, the Bethe Prize of the American Physical Society, and the Henry Norris Russell Lectureship of the American Astronomical Society—the highest honor an astronomer can receive.

Upon his retirement from Harvard in 1999, Cameron accepted an appointment at the Lunar and Planetary Laboratory of the University of Arizona in Tucson. There he and Betsy lived in the Academy Village, a non-profit organization devoted to life-long learning. Sadly, Betsy, his loving wife of forty-six years, died in 2001; they had no children. Those of us who were lucky enough to know Al Cameron well remember him as an exceptionally talented and dedicated scientist, a wise counselor, and a witty person. Few are those who cross one's path with all of these qualities; Al Cameron was one of them.

Respectfully submitted,

Alexander Dalgarno
James Moran
Dimitar Sasselov
Patrick Thaddeus
Friedrich Thielemann
Gerald Wasserburg
John Wood
George Field, Chair