Arthur Dodd Code

August 13, 1923–March 11, 2009
Elected to the NAS, 1971

A Biographical Memoir by David H. DeVorkin and Jordan D. Marché II

Figure 1 Arthur Dodd Code. *Photograph courtesy of Douglas Code.*

In December 1959, Arthur Code was one of eight astronomers called together by the American Astronomical Society to offer their views on making astronomical observations from above the Earth's atmosphere. Code then gave a talk entitled "Stellar Astronomy from a Space Vehicle." In consonance with his colleagues, his message was clear: "The opportunity to carry out astrophysical investigations throughout the entire electromagnetic spectrum, through the use of space vehicles, cannot fail to have a tremendous impact on the future course of stellar astronomy."[1] The presenters covered the entire known electromagnetic spectrum. Code covered many problem areas, concentrating on his and others' efforts to open the ultraviolet and extreme-ultraviolet universe. He spoke only of the scientific questions, not the technical challenges. Yet it is of importance to appreciate that his legacy is one of overcoming those challenges.

By 1968, Code was one of the lead astronomers preparing instruments for the first Orbiting Astronomical Observatory (OAO). He was invited to speak and review progress on the decade-long venture. But he also made it clear that this was not a singular effort. Before naming the members of his Wisconsin team, he acknowledged the huge scale of the effort: "Every stream of bits of data from the OAO promises something new and exciting and it has been so for us. When I say 'us' I mean the many very capable NASA scientists and engineers who had devoted so much effort to bringing about the successful operations of this first orbiting observatory."[2]

These two citations neatly encapsulate Code as an astronomer and a compassionate team leader in the first four decades of space astronomy.

Early Life and Education

Arthur Dodd Code was born in Brooklyn, New York, on August 13, 1923, the only child of Jessie May Dodd from Detroit and Lorne Arthur Code from Canada. The family moved around a lot in Code's childhood years owing to his father's variety of jobs, from running a gas station in Florida to working for Goodyear in Ohio, and later returning to the New York area. The family worked as a team, improving their living quarters and making furniture. Code's maternal uncle, Russell Dodd, a science teacher, lived with them in New York, and Code recalls that he had a "profound influence" in his life, starting at age ten. His uncle shared his library with Code, who became attracted to books exploring modern astrophysics, rather than traditional astronomy. Arthur Eddington's *Stars and Atoms* and James Jeans's *Mysterious Universe* were most enticing, and they propelled him, by his high school years, to try to read Eddington's more thorough review, *Internal Constitution of the Stars*.

Code liked to build things, from a neighborhood telegraph network with friends (he continued with ham radio all through his life), to woodworking in their basement under the guidance of his uncle, who he recalled became something of a "big brother." He considered building a telescope but preferred to learn about astronomical techniques from his reading. He learned the constellations while a Boy Scout and from visits to the Hayden Planetarium.

Excelling in high school, Code set his sights on college. His parents supported this, as they missed the opportunity themselves. But they were not too excited about his choice of astrophysics. Still, he collected college catalogues and considered the University of Michigan, his uncle's alma mater, but soon decided on the University of Chicago, attracted by its Yerkes Observatory. He was accepted in 1940 and was supported by his family and took on student jobs. Code joined the U.S. Navy in 1943, again following his uncle, as a selective volunteer after he received a draft notice.

Code became an electronics technician in the Navy. His telegraph hobby had blossomed into ham radio, and this became his service role, eventually becoming an instructor at the Naval Radio Materials School at the Naval Research Laboratory in Washington, D.C. That post allowed him to take night classes locally at George Washington University, where he especially enjoyed studying stellar structure guided by George Gamow and where he received a sizeable portion of his formal training in physics and mathematics.

After the Navy, in 1945 Code returned to the University of Chicago and had accumulated enough credits to gain access to the astronomers at Yerkes, including Otto Struve, Jesse Greenstein, and Gerard Kuiper. By the summer, Code had become a graduate student there, even though he had not formally completed his undergraduate program. In addition to his coursework, Code assisted the Yerkes astronomers in improving the electronics for a variety of data reduction machines, such as a microphotometer. But tellingly, he recalls that it was during one of his degree examinations that Albert Hiltner asked him how he would modify a telescope to work on the Moon. His answer was perfect: all-reflecting optics to reach the far ultraviolet.

By then, the worlds of electronics and optical design were coming together. Code became fascinated with using image orthicons as detectors, vastly improving the quantum efficiency of telescopes. At the time, Joel Stebbins, at the nearby University of Wisconsin–Madison and a leader of the astronomical community, predicted that advances in detectors would obviate the need for larger telescopes.

At first, Code assisted Hiltner in building photoelectric scanning devices, using simple photocells.[3] He did his master's thesis on an observational problem working for William Morgan but became fascinated with theoretical astrophysics and worked on radiative transfer problems under Subramanyan Chandrasekhar for his Ph.D. in 1950.[4,5] As he completed his thesis, he became increasingly aware of the fact, as he noted in his oral history, that, "At that time, stellar atmosphere theory was far ahead of observations. That's why I wanted to build photoelectric spectrographs and try to make energy measurements of stars."[6]

Upon graduation, Code had options: postdoctoral fellowships at Princeton University to continue along theoretical lines, or at the McCormick Observatory at the University of Virginia to build better photoelectric detector systems. He chose the latter, but in less than a year, Albert Whitford invited him to the University of Wisconsin's Washburn Observatory. He eagerly accepted.

University of Wisconsin and Mount Wilson-Palomar

Wisconsin in many ways pioneered the application of photoelectric technologies to astronomy in the United States.[7,8] Because of this legacy, large observatories in the west, including Mount Wilson, Palomar, and Lick, sought out Wisconsin astronomers with expertise in instrumentation, giving them coveted observing time on their telescopes. Madison was also close to Yerkes, and so at Madison, Code could be close to Morgan and other staff actively engaged in one of the most intriguing problems in astronomy of the day: mapping out the spiral structure of the Milky Way. Spiral structure was first detected by Dutch radio surveys, but because optical evidence was considered the dominant means of discovery and elucidation in the day, confirmation was critical. Morgan had made an auspicious start, but there were puzzling discrepancies between the optical and radio data regarding the structure and dynamics of the arms. Over the next several years, Morgan, aided by Whitford and Code in Madison, tried to understand the discrepancies and managed to reduce them in a series of highly cited papers. As part of this effort, in 1953 Code spent six months in South Africa to complete their survey of the Galaxy's structure.

In 1956, Code was offered a permanent staff position at Mt. Wilson-Palomar that gave him regular access to the 200-inch telescope. But two events changed his direction completely. One was Sputnik and the National Academy of

Science's appeal to astronomers to think of what they could do with a 100-pound satellite. The other was Whitford's departure from Washburn, opening the director's chair, and the possibility of creating a new program focused on space astronomy. Code, who by then was a member of an ad hoc Space Science Board committee to deliberate over the architecture of a space astronomy program, eagerly accepted the challenge, and by 1958 had gathered staff to begin experimenting with a range of small instruments flown first on balloons and then on the X-15 aircraft. Their focus was on the ultraviolet universe, beyond the blocking caused by the Earth's atmosphere. Code's group faced all the technical challenges of creating an instrument system that could be stabilized and pointed to specific targets. Their first targets were hot O and B type stars, which they observed with a small photoelectric telescope using blue and ultraviolet filters—their first step toward flying a 100-pound satellite.

Figure 2 Code (bottom left) and his team with a prototype payload for the WEP high-speed photometer, 1966. *Photograph by John Wolf, courtesy of the University of Wisconsin System, Board of Regents.*

Orbiting Astronomical Observatory and Hubble Space Telescope

In 1959, Code formalized his growing group of scientists and engineers by establishing the Space Astronomy Laboratory (SAL) to organize complex functions such as instrument design, construction, contracting, and data analysis for their continuing X-15 and sounding rocket projects. But soon a major project dominated their efforts, spurred on by NASA's decision to fly platforms for an array of instruments, rather than single flights. This decision also increased the payload capacity well beyond the 100-pound limit. Code's payload, called the Wisconsin Experiment Package (WEP), was chosen to fly on NASA's first Orbiting Astronomical Observatory (OAO), which launched in April 1966 but soon failed. Code's team, however, was already well along in building another similar payload to perform a variety of narrow-field spectrophotometric observations in the far ultraviolet. Launched in December 1968, WEP performed successfully for more than four years and collected data on more than a thousand celestial objects across the ultraviolet sky. The Wisconsin Experiment Package was paired with a Smithsonian payload called Celescope, an array of four ultraviolet telescopes designed to map the entire sky. The two payloads complemented each other, but of the two, WEP proved to be far more successful.[9,10]

Despite the mission's ongoing scientific success, a significant threat to OAO-2's longevity arose in spring 1971. As the manned Apollo missions were winding down and prospects for the coming era of the Space Shuttle were growing, NASA's congressionally approved budget was facing some of its first-ever declines. Informally, the OAO-2 mission was slated to be terminated on June 30, 1971. In response, Code's team launched an intensive grassroots lobbying effort within the American astronomical community. A barrage of letters and phone calls seeking continued support for the OAO-2 mission was directed to U.S. senators and representatives and NASA associate administrator John Naugle. The effects of this lobbying effort were swift and decisive. On April 30 and May 10, 1971, Naugle sent telegrams to some two dozen individuals, affirming that NASA "funds have been reprogrammed" and support for OAO-2 would continue "through December 1971."[11] Never again was funding for the OAO-2 mission threatened.

Along with a major monograph[12] and concurrent review paper,[13] Code and his colleagues published around forty papers on their OAO-2 results, including two atlases of UV spectra and two catalogs of filter photometry data.[14-17] Overall, these reports have garnered well over a thousand citations.

OAO-2 was the first true stellar space observatory that embodied both remote and automatic modes of operation. The bulk of this accomplishment centered around the remote operating systems needed to point, slew, and control the spacecraft while it was in orbit. For this reason, OAO-2 represented a greater technological leap forward in its day than even the much larger Hubble Space Telescope, launched in 1990. In turn, OAO-2's collection of UV data marked the first significant opening of the electromagnetic spectrum for non-solar targets in wavelengths shorter than visible light. That quest characterized much of astrophysical research across the remainder of the twentieth century.[18]

At the same time, OAO-2 operations marked another significant transition in astrophysical research. This trend was the growing reliance placed on digital means of data acquisition, storage, transmission, and reduction that is now practiced throughout the discipline. As Code presciently observed, "high speed computers are essential to the astronomer" for conducting these multiple tasks.[19] Yet, this transition first occurred within the context of mainframe and mini-computing environments that took place well before the 1970s advent of personal computers and charge-coupled devices (CCDs) or the 1990s creation of the Internet.[20]

Between the OAO launches, Code's SAL colleagues also developed the Wisconsin Automatic Photoelectric Telescope (or APT). Carrying an 8-inch reflecting telescope and photometer identical to those used on WEP, the ground-based telescope was driven by a PDP-8 mini-computer and routinely collected atmospheric extinction data. The APT has been dubbed the first "robotic" telescope.[21]

With WEP operating in orbit, Code and his group continued to plan for more payloads. Code was always fascinated by the prospect of new instrumentation and was never single-threaded. Nor did he abandon ground-based astronomy. He was chair of the Scientific Committee at the Kitt Peak National Observatory and helped to create its Space Division, with sights set on orbiting a large telescope in the class of what became the Hubble Space Telescope. By the mid-1970s, he was also gearing up for payloads on Spacelab/Shuttle, exploring how to upscale his many payload designs, including improved means of control and data collection. He was an ardent promoter of advancing space astronomy at all levels. In the 1970s and 1980s, he teamed up with others to observe with the International Ultraviolet Explorer as well as to propose a major instrument for the planned Astro-1 payload for repeated Space Shuttle flights.

What became the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE) was one of four large instruments on a platform set in the Shuttle's payload bay. Meant to be a general-purpose facility, it engaged seven universities and observatories as well as the Goddard Space Flight Center and was originally targeted to meet Comet Halley in 1986. WUPPE employed a half-meter Cassegrain system feeding a spectropolarimeter sensitive enough to reach sixteenth magnitude in the far ultraviolet. Astro-1 flights began in December 1990, so it was too late for Comet Halley. But throughout the 1990s, flying on the successor Astro-2 platform, Code and his colleagues observed a wide range of objects, from hot stars to novae, the interstellar medium, and quasars. By then, Code was also using the Hubble Space Telescope to make complementary observations.

Code was deeply involved in the development of what became the Hubble Space Telescope in conceptualizing, campaigning, planning, organizing, and managing the overly complex and controversial effort. He had long been thinking of what a "large space telescope" would be like, and as a senior member of the board of the Association of Universities for Research in Astronomy (AURA) in the mid-1970s, he was asked to lead a group to explore options for its eventual management structure. This led to the creation and siting of the Space Telescope Science Institute (STScI) at Johns Hopkins University, with Code as its "interim" director for nine months in 1981. Consequentially, Code's involvement naturally brought his Wisconsin group into the picture, and several of them, headed by Robert Bless, proposed a major instrument, a high-speed photometer, that was chosen for the first round of axial instruments on what was now called the Hubble Space Telescope. The effectiveness of Wisconsin's High-Speed Photometer (HSP) was unfortunately severely compromised by the flaws in the telescope's main mirror, discovered after launch. So, when NASA decided to correct the mirror's optics by installing a new corrective optical system in one of its axial bays, the instrument it chose to swap out was the HSP. Naturally, this was a blow to the Wisconsin group, but they did not skip a beat, letting the returned instrument be the subject of studies evaluating the effects of being in space for three and a half years.

Over the years, as Code's status and visibility grew, committee work demanded more of his time and energy. He was happy to be relieved of his interim directorship as well as his chair of the Wisconsin department, but his commitment to the discipline was unwavering. He met his many obligations to Wisconsin, AURA, the National Academy of Sciences, and NASA, but by his very nature and his continuing intense devotion to his science, he became something of a folk legend in those circles. For instance, the AURA committee that he headed for the management of the Space Telescope became known as the "Code uncommittee."[22] His personal recollection of this designation, in a small collection of notes and commentary, offers insight into the man's view of life and personality:

> There was at one time in government circles a law attributed to me referring to committees. Code's law of committees read "The first action of any Committee should be to entertain a motion to disband the committee." I did not actually state that. I was in fact referring to the value of a particular class of committee, however, those committees who are to review or evaluate the report of another

> committee. Code's Law, however, did have one salutary corollary. At this time, I was involved in an excessive number of committees but then the invitations to serve on committees declined significantly.[23]

Nevertheless, his notes also reveal his intense devotion to his science: "Accept the red tape and push on to the objectives.… [T]he more ambitious the more imaginative the more they propel.… Man will not destroy himself if he has so much to live for."[24]

Code the Mentor

Across his lengthy career, Code supervised twenty-four doctoral students and their dissertations. Two of these (Bahng, Melbourne) were at the California Institute of Technology, and the remainder all took place at Wisconsin. Philip M. Solomon's dissertation (1965) was co-directed with Robert Bless. (Table 1).

Table 1 Ph.D. dissertations supervised by Arthur D. Code, 1957–1990

John Bahng (1957)	John S. Gallagher III (1972)
William G. Tifft (1958)	Daya P. Gilra (1972)
Kenneth L. Hallam (1959)	John P. Apruzese (1974)
William G. Melbourne (1959)	Nelson M. Hoffman III (1974)
Donald J. Taylor (1963)	Bernhard M. Haisch (1975)
Martin S. Burkhead (1964)	John E. Davis (1976)
Natalie A. Satunas (1964)	Robert J. Panek (1976)
Philip M. Solomon (1965)	Andrew Katz (1977)
Michael F. A'Hearn (1966)	David P. Huenemoerder (1982)
Mark Daehler (1966)	Marc A. Murison (1988)
Susan M. Simkin (1967)	Barbara A. Whitney (1989)
Charles F. Lillie (1968)	Spencer A. Stanford (1990)

Awards and Honors

Code received many awards and honors over the course of his career, including the Professional Achievement Award of the University of Chicago Alumni Association (1969), NASA's Exceptional Public Service Medal (1970), and its highest honor, the Distinguished Service Medal (1992). He was elected to the National Academy of Sciences (1971) and the International Academy of Astronautics (1972) and was named a Fellow of the American Academy of Arts and Sciences (1974). He was elected vice-president (1976–1978) and president (1982–1984) of the American Astronomical Society. He was also a member of the Board of Physics and Astronomy of the National Research Council. His numerous achievements reflected his diverse competencies as both a theorist *and* experimentalist and observer. For example, even before the Space Age began, Code and William Baum photometrically observed a stellar occultation by the planet Jupiter that enabled a determination of the mean molecular weight of gases in the Jovian atmosphere.[25] First developed in this paper, the so-called "Baum-Code equation" has been widely utilized to model a variety of occultation light curves.

Retirement and Later Life

Code retired from Wisconsin in 1995, but not from astronomy nor from his lifelong passion for ham radio, for which he obtained the rank of Amateur Extra, the highest class of license from the National Association of Amateur Radio, and was able to choose his own "vanity" call sign, AD7C.[26] Code relocated to Tucson, Arizona, and continued programs and plans relating to the further development and strategies for AURA's Kitt Peak National Observatory, which he had helped to establish in the late 1950s. He was named an adjunct professor at the University of Arizona's Steward Observatory, which brought him to the center of a project Wisconsin had been devoted to for several years as part of the WIYN Consortium. Composed of Wisconsin, Indiana University, Yale University, and the National Optical Astronomy Observatory (NOAO), it eventually built what is the second largest optical telescope, a 3.5-meter, on Kitt Peak at the WIYN Observatory.

On March 11, 2009, Code passed away at Meriter Hospital in Madison, Wisconsin, because of complications from a worsening lung condition. At the time of his death, he was the Joel Stebbins and Hilldale Professor of Astronomy Emeritus at the University of Wisconsin–Madison.[27] He was survived by his wife of sixty-five years, Mary Ella Guild, whom he met in his first year at the University of Chicago and married during his Navy service. She became a social worker and worked for some thirty years for a variety of services. They raised four children: Alan Dodd Code, Douglas Merritt Code, Edith Louise Code, and David Arthur Code. Born Episcopalian, in adulthood Code believed that his view of life did not "fit in" with highly structured organized religion. After their first three children were born, he and his wife, born a Quaker, joined the First Unitarian Society of Madison, where they "appreciated the openness and intellectual atmosphere."[28] A fitting description of Code's life and astronomical career.

Acknowledgements

Code's working papers and an oral history, along with Space Astronomy Laboratory records, are held in the archives of the University of Wisconsin-Madison Libraries and the American Institute of Physics Niels Bohr Library. We appreciate the insights provided by Alan Code and Anthony Lattis, and the images provided by Douglas Code and the archives of the University of Wisconsin.

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