Carl Sagan

November 9, 1934 — December 20, 1996

Carl Edward Sagan, David Duncan Professor of Astronomy at Cornell University, who died on December 20, 1996, was an enthusiastic scientist of great breadth, and a preeminent spokesman for science and for critical thinking. In the exploration of the solar system, the technical achievement for which our generation will be remembered, Carl was a pivotal figure.

The son of a garment worker from Russia, Sagan was born on November 9, 1934 in Brooklyn, New York. The University of Chicago granted Carl two undergraduate degrees and a Master's, all by the age of 20, before he continued for his Ph.D. degree there under Gerard Kuiper, at the time America's only full-time academic planetary scientist. Carl spent postdoctoral years at Berkeley and then joined the geneticist Joshua Lederberg at Stanford. After a faculty appointment at Harvard, Carl came to Cornell in 1968 where he remained.

Sagan's publications, more than 600 in number, spanned a remarkable breadth of fields. Among his earliest papers, written while in his early twenties, are discussions of the synthesis of complicated molecules by natural processes in early reducing atmospheres and of lifelike forms in meteorites, showing the direction of his emerging interests. The recent discovery of putative microfossils in a Martian meteorite has rekindled interest in these topics. The possibility of life elsewhere was his scientific passion, and much of his work touched on some aspect of this, often by pointing out the harshness of our own surroundings.

SETI, the search for extraterrestrial intelligence, gained scientific respectability following Carl's first book as an author, in which he heavily annotated a slender volume earlier written by the distinguished Soviet astrophysicist, I.S. Shklovskii. He participated in several SETI programs, most recently with Jim Cordes. With support from the 100,000-member Planetary Society, which Carl and Bruce Murrary founded to involve average citizens in space exploration, Harvard's Paul Horowitz is now pursuing a multi-million channel search. The LAGEOS, Pioneer, and Voyager spacecraft carried messages designed by Carl, Frank Drake, and others, intended ostensibly for any extraterrestrials who might happen upon the craft; the real purpose (well achieved) was to advertise to other humans that our species had begun to visit the stars.

Most of Carl's planetary studies arose out of his participation in spacecraft missions. Carl was a member of the Infrared Radiometer Team for the Mariner 2 space mission to Venus, the earliest successful interplanetary flight, and wrote a series of papers during the 1960s with the late James Pollack, Carl's initial graduate student and

long-time collaborator on the radiation balance of the Venus atmosphere. He argued, correctly as it turned out, that a strong greenhouse effect warms Venus, thereby explaining the till-then mysterious high brightness temperatures observed by microwave measurements.

From 1966-73, Sagan was on the Imaging Team of NASA's Mariner 9 orbiter of Mars. Prior to the spacecraft's launch, he and Pollack suggested that seasonal variations detected in Martian surface markings by telescopic observations were caused by windblown dust. The Mariner 9 imagery verified this, and even today the most complete information concerning the distribution of global surface winds on Mars comes from mapping eolian streaks in spacecraft images.

The 1976 NASA Viking Mission to Mars placed two spacecraft in orbit to monitor the planet, and two landers on the surface, principally to carry out biological experiments. Sagan was a member of the imaging teams for both the landers and on the orbiters. These missions produced the first detailed maps of the surface of another planet, and the first in situ study of another planet. Together with Pollack and Joseph Veverka, Sagan analyzed the nature of wind erosion on Mars, and mapped surface erosional wind indicators. With Brian Toon and Peter Gierasch, he proposed climate change mechanisms for Mars in an effort to explain the puzzling drainage patterns that indicated water once flowed on a planet whose temperatures are currently below the triple-point temperature of water.

From 1970-90, Sagan was part of the Imaging Team for the Voyager missions to the outer solar system that made close flybys of the four gas-giant planets and of Saturn's satellite Titan. Surfaces and atmospheres in the outer solar system contain dark coloring agents in the solid form whose spectroscopic signatures are inconclusive and whose composition remains uncertain. Sagan, his students, the late Reid Thompson and Bishun Khare, argued that the dark materials are produced by photochemistry that leads to complex hydrocarbons formed by the action of sunlight on ubiquitous methane. They demonstrated the process in the laboratory, and carefully measured the optical properties of the products from the infrared through the visible.

By the 1980s, it had become clear that dust in the dry atmosphere of Mars affects atmospheric and surface temperatures, and that interannual differences in dust storm activity is a major cause of climate variability on Mars. This information, combined with his longstanding interest in radiative heat balance, led Sagan, together with Brian Toon, Richard Turco, Thomas Ackerman and Pollack, to explore the thermal effects of atmospheric soot and dust following a major nuclear exchange on Earth. The "Nuclear Winter" image that emerged from this work in 1983 stimulated wide discussion and study of possible global consequences of large scale warfare. The

size of the effect, even its sign, remains controversial, but the failure of national security agencies to imagine this horrendous outcome highlighted the limitations of previous models.

Carl was an Interdisciplinary Scientist on the NASA Galileo orbiter and probe mission to Jupiter, which was launched in 1989 and arrived at Jupiter in late 1995. His preparations for this experiment included extensive laboratory measurements, in collaboration with Khare, Thompson and Gene McDonald, of the optical properties of candidate organic materials that might be identified on Jupiter or its satellites. He became ill just before data began to be returned.

As a first-generation planetary explorer of the first rank, Sagan enormously influenced the direction of the early NASA program, not so much in mission details (although, as mentioned above, he was active in the Mariner, Viking, Voyager and Galileo flights), but through the public attention that he brought to these enterprises and through his access to policy-makers. He was an unwavering critic of NASA's manned space program, including the Space Station, and a staunch advocate of unmanned planetary exploration.

Planetary studies was born as a scientific discipline three decades ago, and Carl was one of its founders. He helped establish the Division for Planetary Sciences (DPS) of the American Astronomical Society, and was one of its first chairmen. Early on, he edited the journal Icarus for 11 years, introducing peer-review and guiding the journal's affiliation with the DPS. Most of all, Carl set the tone for the discipline, through his infectious enthusiasm about space exploration, his scientific generosity, and his interdisciplinary interests. He enticed students and faculty, including ourselves, to join him in the fun of exploring a previously unknown Solar System. In addition to others named above, David Morrison, Dave Pieri, Kathy Rages and Chris Chyba, were his students who are still influential in space exploration; although not officially his advisees, Steven Soter, David Stevenson, William Newman and Steve Squyres were greatly influenced by Carl as graduate students at Cornell.

Carl's talent as a popularizer of science set him apart. A remarkably gifted writer, he was aptly called the poet laureate of science. As James Michener wrote when reviewing the book, *Cosmos*, "His style is iridescent, with lights flashing upon unexpected juxtapositions of thought." *Dragons of Eden*, Sagan's ruminations on the evolution of the human brain, received a Pulitzer Prize. All told, his books stood on best seller lists for more than three years. At his death, he was co-producing the movie, "Contact," based on his novel, and the Omnimax film, *Comet*.

The Emmy and Peabody award-winning "Cosmos" television series, written with his wife-to-be, science author Annie Druyan, and Soter, was seen by half a billion viewers worldwide. It was a visually stunning amalgam of

anthropology, history, biology and astronomy, that showed how our changing perception of the Universe led to a new view of ourselves. In this series and especially during his frequent appearances on Johnny Carson's couch, Carl's charm, puckish sense of humor and boyish good looks overturned the popular perception of the scientist as a remote, stoop-shouldered character in a white lab coat. Suddenly science was interesting and woven into the human fabric.

Perhaps Carl's greatest public influence came through his columns in *Parade*, the Sunday newspaper supplement with a circulation exceeding 80 million. Here, sometimes collaborating with Annie, he shared his wonder at the Universe's beauty and he explained difficult scientific concepts, while simultaneously chiding the public for tolerating scientific charlatans. Because of his interest in exobiology and his visibility, Carl was frequently drawn into public debates about all manner of pseudoscience: from UFOs to parapsychology. With sharp wit, he argued vigorously for rationality and the scientific method, maintaining that the known world was fascinating enough; one need not look for extraterrestrials in every unexplained happening. This campaign led to Carl's most recent book, *The Demon-Haunted World: Science as a Candle in the Dark*.

Not an aloof academic, Carl ventured frequently into debates with public policy implications, such as the already mentioned Nuclear Winter, the reduction of nuclear stockpiles, the hazard posed by asteroid impacts, the best way to destroy threatening asteroids, and strategies to get the superpowers to explore Mars together. In the early 1990s, he brought together a broad coalition of scientists to alert the world's religious leaders, and ultimately its politicians, that the environment was in a crisis that would profoundly affect all the world's peoples.

Sagan received more than twenty honorary degrees, and numerous awards for his pioneering efforts in space exploration, and for his writing and public service. Yet, this most widely known scientist of his generation was never admitted to the U.S. National Academy of Sciences, reportedly because he was blacklisted at the last moment by a few members as someone whose pure scientific accomplishments were insufficient for membership. The paradox is that others have become academicians because of their influence in their field or their administrative positions. Nevertheless, in the last year of his life, Carl was awarded the Academy's Public Welfare Medal, its highest honor.

In a similarly odd twist, Carl was occasionally dismissed as a "mere" science popularizer by some scientific colleagues. His accomplishments in this arena, which would have been considered remarkable had he been a full-time journalist or author, were judged somehow less worthy because of his scientific training and professional standing. Yet most scientists agree that, strictly from self-interest, our community should be urging members to be engaged in interpreting scientific ideas and bringing critical thinking to the public at large.

Every life cut short is a tragedy. Perhaps the most poignant aspect of Carl's death is that life elsewhere—the search that was his scientific passion—may soon be found.

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