

## **Carl Sagan: The People's Astronomer**

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### **Introduction**

Carl Sagan was the world's best known scientist in the late 20th century, serving as our guide to the planets during the golden age of solar system exploration. He was both a visionary and a committed defender of rational scientific thinking. For a time, he transcended the usual categories of academics to become a true celebrity. His life illustrates both the advantages (wealth, fame, access to the seats of power) and burdens (loss of privacy, stress, criticism from academic colleagues) this status implies.

Sagan was propelled on his academic and public careers by a wealth of talent, a large share of good luck, and an intensely focused drive to succeed. His lifelong quest was to understand the universe, especially our planetary system, and to communicate the thrill of scientific discovery to others. A natural teacher, he loved to explain things and never made a questioner feel stupid for asking. Although Sagan had broad intellectual interests, his pursuit of his career left little time for other activities: he did not play golf or follow sports, take up painting or cooking or photography, sing or play a musical instrument, join a church or synagogue, or watch much television or movies. His first two wives complained that he devoted insufficient time to his marriage or his children (1). It is perhaps a matter of personal taste whether we attribute this drive to personal ego or a genuine commitment to educate and inspire people about science. Undoubtedly there were elements of both motivations present.

Many physical scientists, especially those engaged in what might be called "exploration science", would like to be able to communicate with the public about their discoveries. Astronomers and planetary scientists as a group have a reputation in academic circles for successful public advocacy, which has helped stimulate relatively large expenditure of public funds to build observatories and support interplanetary probes. In spite of good intentions, however, few of these scientists become adept at the techniques of explaining technical subjects in terms that are readily understood by the lay public. Even fewer are willing to take the time to patiently answer journalists' questions, to sit still for application of makeup for television appearances, or to faithfully return reporters' calls even when they interrupt a meal or a lab experiment. They might like to be great communicators, but they lack the skills and the commitment. They also recognize that academic rewards generally come to the best researchers, with limited honor associated with excellence in teaching and practically none for public outreach. Sagan was different. He recognized his talents and teacher and popularizer and decided to make such outreach a major aspect of his career.

Born in 1934, Carl (Edward) Sagan (2) grew up in a working-class Jewish neighborhood of New York and attended urban public schools in New York and New Jersey. His father emigrated to the US from Ukraine as a boy, while his maternal grandparents came from the Austro-Hungarian Empire. As a child, Sagan read what science books he could find, but he especially enjoyed science fiction. The University of Chicago provided him scholarship support when he entered in 1951, and there he absorbed the broad-based "great books" program for a liberal education as well as pursuing his love of astronomy and biology. He continued at Chicago for graduate work, receiving his doctorate in astronomy in 1960. After two years as a postdoctoral fellow in biology at Berkeley and Stanford, he joined the Harvard astronomy faculty as Assistant Professor. Denied promotion at Harvard, Sagan moved to Cornell in 1968, becoming

David Duncan Professor of Astronomy and Director of the Laboratory for Planetary studies. Sagan married three times (3) and had five children. He died in 1996 from pneumonia in association with a rare blood disease against which he had been struggling for the final two years of his life.

### **Academic life**

Although best known to the public as a popularizer, Sagan first distinguished himself as a research scientist. His accomplishments in research made it much easier for his academic peers to accept him as a spokesperson for science. Sagan loved the research process, especially when it was combined with the exploration of new worlds. As he often noted, only one generation was privileged to grow up when the other planets and their moons were little more than dim points of light in the night sky, and to see them emerge as unique worlds with their own geological and perhaps even biological history. Sagan played a major role in defining two new disciplines: planetary science and exobiology. As a leading consultant to NASA, he also helped chart the exploration of the solar system by spacecraft.

With academic training in both astronomy and biology, and initially stimulated by a thesis advisor (Gerard P. Kuiper) who shares with Harold Urey the credit for founding modern planetary science, Sagan brought a unique breadth to the emerging new fields of planetary science and exobiology. As early as 1963, Kuiper wrote about his former student that “Some persons work best in specializing on a major program in the laboratory; others are best in liaison between sciences. Dr. Sagan belongs in the latter group” (4).

Sagan was an “idea person” and a master of intuitive physical arguments and “back of the envelope” calculations. He usually left the details to others, and almost all of his published papers were collaborations. Much of this work was done with students, many of whom went on to become leaders themselves in planetary science. These included James Pollack (winner of the Urey Prize for most outstanding young planetary scientist), David Morrison (Director of Astrobiology and Space Research at NASA Ames Research Center), Brian Toon (leading researcher on ozone depletion and atmospheric evolution), Steven Squyres (Principal Investigator for the forthcoming Mars Sample Return missions), and Christopher Chyba (Chair of the NASA planetary exploration advisory committee), to name just a few. Unlike some famous academics, Sagan set high value on proper recognition for young scientists, and most of the papers he published have others as lead author. On much of his later work, including the famous TTAPS paper on nuclear winter (of which more later), his name appears last among the listed authors (5). Throughout the 1970s and into the 80s, he also edited the foremost professional journal in planetary science, *Icarus*.

Sagan’s most important early research dealt with the atmosphere of the planet Venus. Discoveries in radio astronomy made when Sagan was in graduate school first suggested that this planet had a massive atmosphere and very hot surface, in contrast to previous speculation that the climate of Venus was more Earth-like. Part of Sagan’s thesis consisted of the first computed greenhouse model for the atmosphere, in which the high infrared opacity of carbon dioxide and water vapor produced a surface temperature hundreds of degrees higher than that of an airless planet. Over the decade of the 1960s he improved these models, working primarily with James Pollack, to develop and refine what remains to this day our basic understanding of the atmosphere of Venus.

Mars was another planet that interested Sagan, and with Pollack he modeled the atmosphere and developed the idea, later verified by the Mariner 9 and Viking spacecraft, that

quasi-seasonal changes observed on the surface were the result of wind-blown dust. He also wrote a series of papers on Jupiter, focused on atmospheric organic chemistry.

From childhood, Sagan had been inspired by the mystery of the origin and distribution of life. This passion led him to study biology and develop collaborations with leading biologists such as Nobelists Stanley Miller, Joshua Lederberg, and George Muller. Early in his career, he received more encouragement from these biologists than from astronomers, many of whom considered planetary studies to lie on the fringes of respectable science, and exobiology to be beyond the pale. A number of his early publications were in exobiology, and at various times he speculated about life not only on Mars, but also on Venus, Jupiter, and even the Moon. He was one of the founders of international interest in SETI, the microwave search for extraterrestrial intelligence, although he himself did not conduct any searches. He established a life-long collaboration with biochemist Bishun Khare and obtained a series of NASA grants to support a Laboratory for Planetary Studies (first at Harvard and after 1968 at Cornell) focused on organic chemistry. Their work played an important role in establishing the importance of organic reactions in the outer solar system, including the possible contribution of organics from comets in creating the conditions for life's origin on Earth.

NASA greatly valued Sagan's contributions to the spacecraft exploration of the planets during its "Golden Age" (roughly 1960-1990). He was a member of science teams selected for the Mariner 2, Mariner 9, Viking, Voyager, and Galileo missions, among others, and served on numerous advisory panels for both NASA and the National Research Council of the National Academy of Sciences. With his quick mind and breadth of vision, he was always a valued contributor to planning sessions and the "quick look" interpretation that followed the first receipt of spacecraft data, although the detailed measurements and modeling were accomplished later by others. His former student Clark Chapman wrote: "A man of vivid imagination, he keeps alive a wide variety of conceptions of planetary environments. By suggesting often outlandish alternatives and challenging traditionalists to disprove them, he has inspired doubts about many accepted theories. Sagan's role is essential for healthy science because a bandwagon effect frequently leads to premature consensus among scientists before equally plausible alternatives have even been thought of, let alone rationally rejected" (6).

Sagan's own excitement with the process of scientific discovery is captured in the following quote, written in the early 1970s: "Even today, there are moments when what I do seems to me like an improbable, if unusually pleasant dream: to be involved in the exploration of Venus, Mars, Jupiter, and Saturn; to try to duplicate the steps that led to the origin of life on an Earth very different from the one we know, to land instruments on Mars to search there for life; and perhaps to be engaged in a serious effort to communicate with other intelligent beings, if such there be, out there in the dark of the night sky" (7).

### **In pursuit of fame**

At the same time he was building up an enviable academic bibliography (8) and record of successful students, Sagan also established a growing reputation as a popularizer of science. His boyish good looks, resonant voice, and ability to explain scientific concepts in terms that lay persons and students could understand, made him a popular teacher and public lecturer. He won teaching awards at Harvard and Cornell, and even in the busiest times of his life tried to keep his hand in undergraduate teaching. In 1966 he first achieved some modest national attention with his book *Intelligent Life in the Universe*. The product of a unique long-distance collaboration

with the distinguished Russian astrophysicist I.S. Skhlovskii, the book presented a fascinating dialogue between the two authors, and it sold 25,000 copies hardbound.

The following year, Sagan wrote an upbeat article on the potential of life on the planets for *The National Geographic*, and he made a few brief TV appearances. Already it was apparent to some that Sagan sought a broader role than that of academic researcher, a concern that contributed to denial of tenure by Harvard University in 1967. He was also acquiring a reputation as someone driven by intense personal ambition, happiest when he was the center of attention. Students loved him, but some fellow academics bristled at what they perceived as self-aggrandizement and pandering to the public. Unlike Harvard, Cornell University was looking for faculty with a potential for stardom, and they provided Sagan an endowed chair and the solid academic springboard he needed for his future rise to fame and fortune (9).

In his early years at Cornell, Sagan pursued one of the themes that motivated much of his life: the quest to improve public understanding of the nature of science. He was a tireless defender of rationality (some would say of scientism) and opponent of pseudoscience. He wanted every citizen to have a "baloney detector" as defense against sham in commerce and politics as well as science. He felt that it was the duty of scientists and scientific societies to face these issues squarely. This conviction led him to participate as a founding member of the Committee for Scientific Investigation of Claims of the Paranormal (CSICOP) and to organize two controversial public symposia at meetings of the American Association for the Advancement of Science (AAAS).

The first AAAS symposium, in 1969, dealt with the reality of UFOs, with J. Allen Hynek and James McDonald defending UFO studies and Sagan, Donald Menzel, and Lester Grinspoon on the attack. The proponents on both sides of the issue were scientists, although they adopted very different approaches to the interpretation of the many anecdotal reports of UFO sightings. Proponents argued that even though there was no individual sighting in which one could make a compelling case for extraterrestrial spacecraft, the sheer volume of reports justified continuing examination and study. In contrast, Sagan emphasized the unreliability of witnesses, the absence of physical evidence of UFOs, and the various alternative explanations including hallucination and self-delusion. He applied a skeptical standard that is often associated with his name: that extraordinary claims require extraordinary levels of evidence or proof (10).

The 1974 AAAS symposium was on the work of popular pseudo-cosmologist Emmanuel Velikovsky. Velikovsky's thesis of global catastrophes caused by numerous planetary encounters within historical times, developed in his 1950 book *Worlds in Collision* and other writings, was scientifically indefensible but had attracted a wide popular following. Unlike the UFO symposium, there were no scientists to defend these ideas (11). Rather, the 77-year-old Velikovsky himself was invited to confront his debunkers. Keay Davidson describes the symposium as follows in his Sagan biography: "The debate would constitute, in effect, an apology to Velikovsky [for previous slights from astronomers], giving him the opportunity to submit his ideas to direct scientific scrutiny. The debate's ultimate goal was not to reassess Velikovsky's ideas (hardly any scientist took these seriously), but, rather, to reassure the public of science's basic fair-mindedness." The confrontation of the patriarchal Velikovsky and his young, brash critic was a clash of egos on both sides. Sagan aimed his remarks, published in extended form in *Scientists Confront Velikovsky* (12), primarily at the public and science journalists. By most accounts he was hands-down winner. Many people credit this debate as the beginning of the end for the Velikovsky cult, which is today reduced to a handful of obscure cranks.

Both AAAS symposia were widely covered by the media and contributed to a growing public recognition of Sagan's name. A further jump toward fame came in 1973 with the publication of one of Sagan's best books, *The Cosmic Connection*. A wide-ranging series of essays, *The Cosmic Connection* was described in *Science* as "39 genuine, vintage Sagan dinner conversations". This description was more accurate than the reviewer may have realized. This book, like all of Sagan's, was dictated. Creating his books and popular articles this way, Sagan simultaneously developed his unique speaking and writing styles. At his lectures, listeners were always impressed by his carefully crafted sentences, and by the way his talks (delivered without notes) seemed to be so well organized. Dictation turned out to be the perfect way for Sagan to organize his thoughts and develop his prose style simultaneously. It allowed him to "write" while traveling or walking on the beach, and it never necessitated his learning to type. It also allowed him to derive multiple value from the same material, typically delivering his message in various lectures, writing it for a magazine article (for such outlets as *Parade*), and using it as the basis for a chapter in one of his books.

*The Cosmic Connection* received glowing reviews (*Washington Post*: "a book that is very nearly perfect"). It also helped open the door to a medium that Sagan seemed destined for: television. In November 1973, he was invited to appear on the popular Tonight Show with Johnny Carson. Handsome, articulate, informal in manner, yet enthusiastically discussing real science (and often the latest results of NASA missions like Viking and Voyager), he captivated both the audience and the host. Over the following 13 years, Sagan appeared on the Carson show 26 times. No matter how pressing his other business, Sagan was always willing to take a break and fly to Hollywood for the Tonight Show. He considered it "the biggest classroom in history." And it made him one of the best-known scientists in the United States.

In January 1974, at the time of Sagan's second appearance on the Tonight Show, *Time* did a cover story on life in the universe, in which it called Sagan "the prime advocate and perennial gadfly for planetary exploration." A few weeks later he published an article in *TV Guide*, the largest circulation magazine in the United States. Sagan was suddenly hot, receiving media attention normally reserved for a select few Nobel Prize winners. He also submitted to a feature interview for the men's magazine *Oui*, an even more unusual activity for an academic.

The widely publicized Viking landings in 1976, by two NASA spacecraft designed to search for life on Mars, provided more exposure. In 1997, *Newsweek* put his smiling face on its cover, a rare accolade for any scientist. Their thumbnail sketch stated: "At 42, Carl Sagan has become the leading spokesman and salesman for the new science of exobiology, the search for extraterrestrial life. Lobbying in Washington, appearing on television talk shows and teaching at Cornell, he is building fresh support for the space program and fulfilling his own fantasies of finding life out there. But some colleagues are exasperated by his freewheeling speculations and question whether the life search is a science at all" (13).

### **Showman of science**

Sagan's next major book was published in 1978. *The Dragons of Eden* was a departure, dealing with an area of science in which he had no special expertise: the human brain. Here Sagan popularized the work of others, primarily Paul MacLean and his theory of the triun brain, and Roger Perry with his concept of a brain split between right and left sides. Perhaps to compensate for his lack of primary knowledge, Sagan worked unusually hard on both content and writing style. Although criticized by many academics as shallow and speculative, the book

was hailed for the clarity and charm of its prose, its wit and elegance. In 1978, *The Dragons of Eden* won the Pulitzer Prize for nonfiction.

With this exposure, Sagan decided to test the capacity of television to bring science to a mass audience. In partnership with engineer and entrepreneur Gentry Lee, a Viking colleague, he formed Carl Sagan Enterprises and began marketing a television series modeled on Jacob Bronowski's *Ascent of Man*. They developed a script, raised several million dollars in support, and hired Bronowski's director, Adrian Malone. At the same time Sagan fell rapturously in love with Ann Druyan, with whom he worked closely for the rest of his life. He and Annie moved to Los Angeles, and production at KCET Public Television started in 1977 on the 13-hour series called *Cosmos*.

His dual commitment to Annie and to *Cosmos* eclipsed Sagan's academic roles. His classes were canceled, and several graduate students who had come to Cornell to work with him chose other advisors instead. Colleagues complained, and there was an effort to force his laboratory out of the Cornell Space Science Building. Meanwhile, his divorce turned into a squalid and expensive legal battle. In Los Angeles, clashes of will between Sagan and Malone almost derailed the entire *Cosmos* effort. (14) Finally, the first production aired in September 1980, accompanied by a promotional effort that exceeded anything seen before in public television. Most reviews were enthusiastic, and suddenly Sagan was a celebrity. The series won the Peabody Award, and eventually more than 400 million people saw *Cosmos* in dozens of countries around the world. The accompanying book, also called *Cosmos*, was on the *New York Times* best seller list for 70 weeks and made him wealthy as well as famous.

In October, 1980, Sagan appeared on the cover of *Time*, shown wading in the "cosmic ocean". *Time* described him as the "Showman of Science" and the "prince of popularizers". They wrote: "Sagan sends out an exuberant message: science is not only vital for humanity's future well being, but it is rousing good fun as well. Watching with wonder -- and no doubt a little envy -- the whirling star named Sagan, some of his colleagues feel that he has stepped beyond the bounds of science. They complain that he is driven by ego. They also say that he tends to overstate his case, often fails to give proper credit to other scientists for their work and blurs the line between fact and speculation. But they probably represent a minority view. Most scientists, increasingly sensitive to the need for public support and understanding of science, appreciate what Sagan has become: America's most effective salesman of science" (15).

Sagan moved back to Cornell after *Cosmos*, but he could not return to the anonymity of the campus, even if he wanted to. People stopped him on the street and interrupted his meals in restaurants to tell him how much they liked *Cosmos* or to ask for his autograph. He also received crank calls and death threats, requiring police patrols of his home and prompting the University to remove his name from his office door and from the Space Science Building directory. But fame had its positive elements. His standard speaking fees rose toward 5 figures, and he demanded first class airfare and private limousine service. He bought a spectacular home modeled on an Egyptian temple, perched on the edge of one of Ithaca's wooded gorges. The Sagens hired a nanny and a housekeeper, and a full time secretary just to answer letters from the public. And he received an unprecedented advance from Simon & Shuster of \$2 million for a science fiction novel to be called *Contact*, before he had written a word. *Contact* was published in 1985, and it was made into a successful film starring Jodie Foster, released in the year after his death.

In his continuing defense of scientific thinking, Sagan's fame brought him a unique role, as described by journalist Joel Achenbach in *Captured by Aliens*. Achenbach noted that once

Sagan achieved superstardom with *Cosmos*, he became the public lightning rod for both the science and the pseudoscience of extraterrestrial life. As the “keeper of the gates” who effectively defined the border between science and pseudoscience, he was actively courted by many fringe figures who sought in his blessing a legitimization of their interests or beliefs. Sagan’s role is especially interesting because he himself was accused of straying beyond the limits of proper science in his pursuit of evidence for life on other planets and his defense of SETI. As Achenbach argues, it was precisely because of his apparent open-minded attitude toward fringe topics that many on the fringe became so bitter when Sagan turned against them (16).

Thanks in part to his mastery of the television medium, Sagan was moving into a world of celebrity where no academic had gone before. He told colleagues that he intended to return to the life of a professor, teaching again and becoming involved with NASA’s ambitious new Galileo mission to Jupiter, but this was not enough. He also wanted to use his new wealth and power to accomplish objectives of more global scope.

### **Making a better world**

Sagan’s rise to celebrity occurred simultaneous with the Ronald Reagan presidency and an escalation of arms spending and cold war rhetoric (17). He was an early opponent of Reagan’s Space Defense Initiative (SDI) or “Star Wars”, and he was able to rally vocal objections from the academic community that questioned both the technical basis for SDI and its potential destabilizing effect on the nuclear balance. Then in 1982, an even more compelling opportunity presented itself to campaign for nuclear disarmament, thanks to research involving two of his former students, Jim Pollack and Brian Toon.

Toon and Pollack were research scientists at NASA Ames Research Center. With colleagues Rich Turco and Tom Ackerman, they were studying the role of dust and atmospheric aerosols in determining global climate. They had been working for several years to understand the effects of martian dust storms and of the dust cloud that enveloped the Earth following the asteroid impact that caused the extinction of the dinosaurs. But in 1982, they had realized that smoke, especially from petrochemical fires, would have a much greater effect on global climate than naturally occurring dust. In fact, it appeared that the smoke from as few as 100 burning cities, when lofted into the stratosphere, could lead to severe global cooling (nuclear winter). Turco and Toon flew to Ithaca in late 1982 to enlist Sagan’s aid, for both the technical aspects of the research and as a means to overcome objections that had been raised within NASA because of the political implications of this work. This collaboration generated the TTAPS paper (named for the first initials of the authors, but with obvious symbolic significance) on nuclear winter published in *Science* in late 1983. The TTAPS authors concluded that even a less-than-full-scale nuclear exchange, especially if it were directed against cities, could cause global cooling and collapse of agriculture. The massive loss of life would hit victor, vanquished, or non-combatant nations alike.

Sagan used all his prestige to argue that these new findings rendered nuclear war obsolete and undermined the concept of massive nuclear retaliation (18). The debate was international, with especially strong reactions from countries that had tried to remain outside the cold war rivalries. Apparently the issue was also widely debated within the USSR, stimulating a rethinking in their military on nuclear war-fighting strategies. But the pro-nuclear forces in the United States counter-attacked vigorously, and they were more than willing to vilify Sagan personally in the process. The *National Review* called nuclear winter “a fraud” and titled one

cover story “Flat-Earth Sagan Falls off the End of the World”. Edward Teller, who at 73 was probably the second best known scientist in the US (19), debated Sagan on nuclear winter before a special convocation of the US Congress. Sagan also led a delegation to meet with Pope John Paul II, who subsequently issued a Papal statement against the build-up of nuclear arsenals. Fortunately, the accuracy of the nuclear winter models has never been tested experimentally, but many people credit this theory, and its advocacy by Sagan, as influential in the move toward nuclear disarmament represented by the START treaties between the US and the USSR.

In parallel with its escalation of the nuclear arms race, the Reagan administration cut back drastically on NASA’s program of planetary exploration. In 1981 they threatened to close down the highly successful Voyager 2 spacecraft before its Uranus and Neptune encounters and to turn JPL into a defense contractor lab. After the *Shuttle Challenger* accident in 1986, the momentum seemed to have left NASA, just when Sagan was advocating an accelerated exploration program in his books and lectures. At the same time the USSR, under the influence of Michael Gorbachov’s reforms, seemed more open to international collaboration. Operating a series of space stations culminating in *Mir*, they tested the ability of humans to live and work for long periods in space, and their new Energia rocket was coming into production. Such a huge rocket was needed for only one thing really: human flights to the Moon and planets (20).

Sagan saw an opportunity to achieve two goals of noble dimension. By working together on missions to Mars, the US and the USSR could build confidence and gain experience that would ultimately defuse the cold war and permit cooperation in many other areas. By pooling their resources, these two space-faring nations could accomplish together what neither could afford alone -- extending human presence into the solar system. A joint Mars program could open the door to the planets and simultaneously ensure peace on Earth.

Sagan was perceived as an enemy by the Pentagon and the Reagan White House. Sensing a better opportunity in the USSR, he became a frequent visitor to Moscow in the mid 1980s. He formed a close working relationship with Roald Sagdeev, the Director of the Space Research Institute in Moscow, and together they opened up the Soviet planetary exploration program, with unprecedented live reporting of the VEGA flybys of Comet Halley in 1986. In 1987, he led an American delegation to a celebration of the 30th anniversary of the first Sputnik, in which the Russians chartered one of their new wide-body Ilushyn airliners to provide direct service from Washington to Moscow. He associated with Soviet Cosmonauts and government officials as well as scientists. For a few years, under his leadership, anything seemed possible. Then the USSR disintegrated, and many of her space scientists found themselves unemployed. With the failure of Russia’s last three planetary missions (all destined for Mars), both the motivation and the capability of Russia to partner in exploration of the solar system evaporated (21).

By the time of the final Voyager encounter with Neptune in 1989, it was apparent that his campaign to promote human expansion to Mars was doomed. Sagan’s Russian friend Sagdeev was emigrating to the US and marrying (of all people) Dwight Eisenhower’s granddaughter. And after a decade of budget cuts, NASA seemed unable to summon the resources even to maintain a modest program of robotic space exploration. The high hopes of the Viking and Voyager era were gone. In a 1989 lecture at JPL, Sagan could not conceal his frustration and disappointment. However, worse personal blows were about to fall.

### **Disappointment and Renewal**

In the autumn of 1990, Sagan made his worst scientific mistake. Iraq had invaded Kuwait, and US President George Bush was forging a military alliance to repel the aggressor.



Kuwait is a major oil producer, and Iraq threatened to set fire to the oil wells. Sagan became concerned that the quantity of petrochemical smoke generated by these oil-field fires could generate a small-scale nuclear winter, endangering crops across Asia and threatening world food production. Of his four TTAPS co-authors, only Turco supported this hypothesis; Pollack, Toon and Ackerman could not see how sufficient smoke could get into the stratosphere. Driven perhaps by hubris, Sagan went public with dire predictions. In fairness, he was careful to keep his predictions conditional, saying only that we could *not* show that massive oil-field fires would *not* have major climatological consequences (a “double negative” logic that he frequently used in his writing and lecturing). In the event, the oil fields were torched in January 1991, the smoke blackened the sky over most of Kuwait and disrupted the coastal ecosystem, but there were no climatic effects, even on a local scale. Sagan was widely criticized, and the episode had the further effect of undermining the credibility of the entire nuclear winter scenario. Toon and Pollack were especially disillusioned.

The next year Sagan was nominated for membership in the National Academy of Sciences. Nobel laureate Stanley Miller was his chief advocate. Academy membership requires distinguished research scholarship, but that is rarely enough by itself to ensure membership. Considerable weight is also given to public service, as well as more political factors such as where you work and who you know. Most colleagues agreed that Sagan’s research record was adequate if not compelling (22), and that his additional journal editorship, government service, and contributions to public understanding of science should have ensured his election. But Sagan had made enemies and inspired jealousy too. He was blackballed in the first voting round, requiring a full debate and vote by the Academy membership. In the final vote he barely received 50% yes votes, far short of the 2/3 majority required for election to membership (23). This decision was widely reported, and Sagan received considerable public and media support, but such outside “interference” in Academy business probably further alienated the members. It was unheard of for the secret deliberations of the Academy to be discussed openly in newspapers and on television.

Two years later, the National Academy awarded Sagan its prestigious Public Welfare Medal, perhaps in partial compensation for his rejection in 1992. The damage was done, however: not only a stinging personal blow, but also an attack on his credibility as a spokesperson for science. For all his accomplishments, or perhaps because of some of them, influential members of the academic “old boys” network never accepted him.

Other problems multiplied. In 1993 the NASA SETI Program, which he had defended on critical occasions in the past, was abruptly terminated by Congress at the instigation of a single member of the US Senate, Richard Byran of Nevada. His book on nuclear winter, written with Turco, sold only a few thousand copies; no one cared much any more about issues of nuclear war. Perhaps worst of all, a book that he and Annie put a great deal of themselves into, *Shadows of Forgotten Ancestors*, did not receive the enthusiastic welcome they expected. Although some reviewers consider it one of Sagan’s best works, it was not a best seller, and the prestigious *New York Times* didn’t even bother to review it.

Perhaps Sagan’s most important contributions in his final years were in his fight against the flimflam of pseudoscience. Throughout the last decade of the millennium, this scourge of public irrationality grew, in astrology, alien abductions, alternative medicine, and any number of other “new age” and “millennial” fads and cults. Sagan had a “bully pulpit” to fight back, and after the death of his friend Isaac Asimov, his was the principle voice in defense of scientific reason in the United States.

His most influential platform was provided by the weekly magazine *Parade*, one of the two most widely read publications in the US (24). His column appeared there regularly for more than a decade, providing a unique opportunity for outreach and education. In this column, he discussed the latest discoveries in science, debunked the purveyors of flimflam, and also delved into sensitive topics of public concern such as abortion and animal rights. His articles in *Parade* provided the basis for many chapters in his final three books, *Pale Blue Dot* (its title based on the distant Voyager photo of Earth (25)) *The Demon Haunted World*, and *Billions and Billions*. *The Demon Haunted World*, subtitled *Science as a Candle in the Dark*, was a passionate defense of science against pseudoscience and irrationality, as illustrated in the following quotes. "It is far better to grasp the Universe as it really is than to persist in delusion, however satisfying and reassuring [that may be]... Superstition and pseudoscience keep getting in the way [of understanding nature], providing easy answers, dodging skeptical scrutiny, casually pressing our awe buttons and cheapening the experience, making us routine and comfortable practitioners as well as victims of credulity... [Pseudoscience] ripples with gullibility. . . The tenants of skepticism do not require an advanced degree to master, as most successful used car buyers demonstrate. The whole idea of democratic application of skepticism is that everyone should have the essential tools to effectively and constructively evaluate claims to knowledge.... But the tools of skepticism are generally unavailable to the citizens of our society.... Those who have something to sell, those who wish to influence public opinion, those in power, a skeptic might suggest, have a vested interest in discouraging skepticism."

Although more demanding and hence less popular than his books about astronomy and planetary exploration, *The Demon Haunted World* is considered by some to be his most mature and valuable publication. Expressing his concerns about the irrationalism that seems to pervade modern society, he wrote: "I know that the consequences of scientific illiteracy are far more dangerous in our time than in any time that has come before. It's perilous and foolhardy for the average citizen to remain ignorant about global warming, say, or ozone depletion, air pollution, toxic and radioactive wastes, topsoil erosion, tropical deforestation, exponential population growth ... How can we affect national policy -- or even make intelligent decisions in our own lives -- if we don't grasp the underlying issues? ... Plainly there is no way back. Like it or not, we are stuck with science. We had better make the best of it. When we finally come to terms with it and fully recognize its beauty and power, we will find, in spiritual as well as in practical matters, that we have made a bargain strongly in our favor."

By this time it was also possible to judge Sagan's influence through his many students. I have already referred to his doctoral students who became leading researchers in planetary science. In addition, he served as a role model in his commitment to education, scientific skepticism, and public outreach. For example, in addition to their research-based Ph. D.s: Clark Chapman wrote two excellent trade books and a regular magazine column on space science; Chris Chyba became a White House Fellow and later the Co-Director of the Stanford University Center for International Cooperation and Security; David Grinspoon wrote a widely praised book on Venus; Steven Soter worked on the staffs of the Smithsonian Air and Space Museum and the American Museum of Natural History; and David Morrison became a successful author of college textbooks in astronomy and planetary science. In addition, there are countless others in all walks of life who credit their interest in science to Sagan, as a teacher, author, or television personality.

Sagan's influence and example also contributed to increasing efforts by scientists to reach out to the press and the public. By the 1980s such professional organizations as the American

Astronomical Society and the American Geophysical Union had appointed full-time press officers and were sponsoring press conferences at their annual meetings. NASA missions also undertook to identify and encourage project scientists to speak with the press, both informally and as official NASA spokespersons. In the 1960s, Sagan was almost alone in his work with the press, but such activity had become relatively common among space scientists two decades later.

The middle 1990s saw restoration of Sagan's influence on NASA. Dan Goldin, who became NASA Administrator in 1993, came from the same tough New York Jewish background as Sagan. Although their personalities were very different, they got on well, and Sagan advised Goldin as he worked to reinvigorate NASA and redirect its goals toward research and development (26). In particular, Sagan helped inspire Goldin's personal commitment to eventual human flight to Mars.

These were also turning into Sagan's twilight years (27). Except for a few meetings with Vice President Gore, he was no longer a celebrity. The Johnny Carson show was long gone, and his books no longer made the best seller lists. Then, in late 1994 Sagan was diagnosed with a rare blood disease called myelodysplasia. He was told that without massive intervention he would be dead in six months, and even with the best care modern science could muster, his chances of survival were no more than even. He fought back bravely and for a time seemed to have conquered the disease, but in the end he succumbed, surrounded by his family, in December 1996.

Cornell's well-respected President Frank Rhodes summarized his impact: "I want to salute Carl Sagan ... as the embodiment of everything that is best in academic life ... in scholarship, teaching, and service ... Carl is an inspiring example of the engaged, global citizen ... [He is] a master of synthesis, and he has used that skill to engage us as a society in some of the biggest issues of our time... With the conscience of a humanist and the consummate skill of the scientist, he address the needs of the society in which we live, and we are the richer for it." (28).

Three years after his death, it is clear that Sagan has no successor. While there are many other scientists who are also outstanding teachers and can explain things well to lay audiences, they lack his charisma and exposure. Or they follow a full-time media career, such as Bill Nye ("The Science Guy"). Sagan was unique in being both a respected research scientist with a chair at a major university, and also a public figure and media star. In a time of increasing specialization, we may never again see an academic who bridges these two worlds so effectively.

### **Endnotes:**

(1) Most of the personal and historical sources on Sagan's life are described and documented in two excellent recent narrative biographies: *Carl Sagan: A Life* by Keay Davidson, 1999, John Wiley 450pp; and *Carl Sagan: A Life in the Cosmos* by William Poundstone, 1999, Henry Holt and Company, 560pp.

(2) Sagan never used his middle name or initial -- a practice that is prevalent among actors and politicians, but less common among scientists, who usually sign their papers with a middle initial.

(3) Sagan's first wife, Lynn (Alexander) Margulis, became a leading biological scientist, elected to the National Academy of Sciences and awarded the nation's highest science honor, the Presidential Medal of Science.

(4) Kuiper, quoted by Davidson in *Carl Sagan: A Life*.

- (5) In Sagan's professional disciplines the order of authors (if not alphabetical) is generally expected to reflect their relative contribution. Only a few senior researchers routinely place their names last in multi-author papers.
- (6) Chapman, quoted by Davidson by *Carl Sagan: A Life*.
- (7) *The Cosmic Connection: An Extraterrestrial Perspective*, 1973, Doubleday 274 pp (re-issued by Cambridge University Press, 2000)
- (8) He kept a meticulous record of all his lectures and popular articles as well as his scientific appointments and publications, generating a *Vitae* at the end of his career that stood about 4 cm high -- the equivalent of a small book in length.
- (9) Cornell University President Frank T. Rhodes said at Sagan's 60th birthday that "I want to bring Carl greetings from all the members of the Cornell Community who owe so much to his leadership over so many years. . . and thank you . . . as an exemplary member of the Cornell community. . . I want to salute Carl Sagan tonight as the embodiment of everything that is best in the academic life and to explain why we are so immensely proud to be able to call him colleague here at Cornell." In *Carl Sagan's Universe*, Yervant Terzian and Elizabeth Bilson, editors, 1997, Cambridge University Press 232 pp.
- (10) Sagan himself was always fascinated by the possibility of life on other worlds, and during his high school and college years he was attracted to the idea that UFOs might be visiting spacecraft. Later his scientific skepticism overcame such romantic delusions, but perhaps Sagan retained some empathy with the UFOlogists at the same time he criticized their naïve interpretation of flimsy and fragmentary data.
- (11) Some critics from outside the physical sciences still question how Sagan and other astronomers could reject Velikovsky without reading his books and carefully studying his ideas. Perhaps they don't understand how readily someone with sound technical training and physical intuition can recognize pseudoscience like that of Velikovsky. You don't have to consume an entire meal of spoiled food to recognize the problem -- one or two bites is enough.
- (12) *Scientists Confront Velikovsky*, edited by Donald Goldsmith, 1977, Cornell University Press 183 pp. Velikovsky refused to publish his paper in the book because he was unwilling to agree to refereeing, page limits, or other editorial controls, so we have no verbatim record of his side in this "debate".
- (13) *Newseek*, August 15, 1977.
- (14) Friends and critics alike agree that the biggest problem with *Cosmos* lay in repeated close-up shots of Sagan, often gazing rapturously into the void. Some of Sagan's friends blamed these on Malone and suggested that the Director included these shots to make Sagan look foolish. Malone said they were Sagan's idea, and Sagan did not realize until the series was aired that they detracted from his image rather than enhancing it. Later Gentry Lee cut the *Cosmos* series for commercial television, eliminating most of the Sagan close-ups to produce a more focused, faster-paced product.
- (15) *Time*, October 20, 1980. Sagan also was on the cover the *United Mainliner* magazine in December 1980, with the ambiguous heading "Pied Piper of Science".
- (16) One account of Sagan's "gatekeeper" role is recounted by Achenbach in *Captured by Aliens: The Search for Life and Truth in a Very Large Universe* (1999, Simon and Shuster 415 pp). Achenbach interviewed Richard Hoagland, author of *The Monuments of Mars* and leader of the "Face on Mars" cult. Hoagland explained that in a public meeting in 1985, Sagan made a comment that those planning NASA missions to Mars should be open to discovering the unexpected. The statement seems innocuous to me, but according to Hoagland, when Sagan made these remarks, he briefly made direct eye-contact with Hoagland, who was among the journalists in the audience. Sagan's innocent comment thus became a coded message encouraging Hoagland to pursue his advocacy of an artificial origin for the Face. Hoagland argued to Achenbach that this "endorsement" legitimized his continuing crusade, even after the Mars Global Surveyor obtained high-resolution photos that dispelled any possibility of an artificial origin for the Face. (Hoagland's response was that the NASA pictures were faked, one of the massive government cover-ups so often cited by people on the fringe).

- (17) The 1980 *Time* that featured Sagan as "Showman of Science" also notes on the cover a pre-election profile called "The Real Reagan".
- (18) In this period, while attending a meeting of the imaging science team for the Galileo spacecraft, Sagan apologized to his teammates about his inability to commit more time to this mission by saying that he was "putting most of my energy into saving the world from nuclear holocaust". Most team members agreed that this effort should indeed have a higher priority for Sagan than planning imaging sequences.
- (19) Years later Teller told me a story of an airport breakfast that he and Sagan shared at this time, where (to Teller's obvious distaste) three strangers came up to ask Sagan for his autograph, but no one seemed to recognize Teller.
- (20) Two 1987 news magazine covers capture the mood: *Newsweek* (August 17) "Lost in Space: How to get America off the ground"; and *Time* (October 5) "Moscow Takes the Lead [in space exploration]"
- (21) The missions were Phobos 1 and 2 in the late 1980s, and Mars 96.
- (22) Michael Shermer presented in *Skeptic* (spring 2000) an objective comparison of Sagan's credentials with that of several well-known members of the Academy, finding that by most measures of academic success (for example, his 23 honorary doctoral degrees) he ranked high, even in this august company.
- (23) Jim Pollack's case may have also confused matters. Most planetary scientists assumed that Jim would be elected to the Academy any time, and many of Sagan's best research papers were collaborations with him. Unfortunately, Pollack died of bone cancer in 1994, before he was formally proposed for election to the Academy.
- (24) Sagan first appeared on the cover of *Parade* on October 2, 1983, with an article titled "What We Learn from Other Worlds".
- (25) Sagan was the chief architect of this experiment, turning the Voyager cameras back toward the Sun to obtain an image of the entire solar system. Like the plaques and videodiscs he designed for the Pioneer 10 and 11 and the Voyager 1 and 2 spacecraft, this photo was a symbol for humanity's first tentative reach toward the stars. Unlike most scientists, Sagan saw the value of such symbols and exploited them to stimulate public interest in space exploration.
- (26) By the time of Sagan's death, NASA's launch rate of robotic science missions had jumped from a low of one or two per year up to nearly ten per year.
- (27) One of the highlights of his last years was a festive 60th birthday celebration held at Cornell with four half-day symposia honoring his contributions in four disciplines: planetary exploration, life in the cosmos, science education, and environmental and public policy.
- (28) In *Carl Sagan's Universe*, Yervant Terzian and Elizabeth Bilson, editors, 1997, Cambridge University Press 232 pp.