Views of a Comet

Comet Halley. Investigations, Results, Interpretations. J. W. MASON, Ed. Horwood (Prentice Hall), Englewood Cliffs, NJ, 1990. In two volumes. Vol. 1, Organization, Plasma, Gas. xxii, 295 pp., illus., + plates. $110. Vol. 2, Dust, Nucleus, Evolution. xxii, 275 pp., illus., + plates. $110. Ellis Horwood Library of Space Science and Space Technology, Series in Astronomy.

In March 1986, four spacecraft (Suisei, Vegas 1 and 2, and Giotto) from the Halley armada of spacecraft passed through the coma (head) of Halley's comet, returning innumerable data of types never previously obtained for any comet. The first direct images of a comet's nucleus have received the widest circulation and publicity, but they represent only a small fraction of the total scientific accomplishment. In addition, comet Halley was the object of perhaps the most extensive remote-sensing campaign ever for an astronomical object. The comet was studied with telescopes on every continent (including Antarctica) and with telescopes orbiting both Earth and Venus.

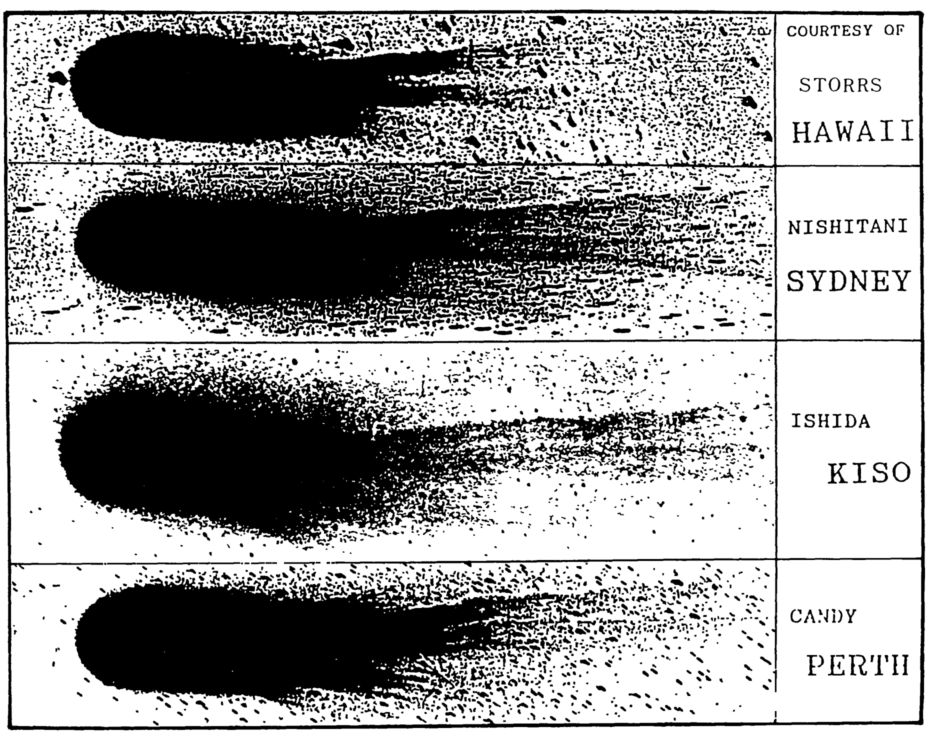
With this wealth of new data, it has been difficult to assimilate all the results and put them together into a coherent new picture of comets. This difficulty is compounded further by our continuing uncertainty about the degree to which Halley's comet is representative of other comets with short (less than 200 years) periods, let alone of all comets. Nevertheless, one can readily identify a few aspects of our picture of comets that have changed drastically or have come into being because of the intensive study of comet Halley.

The first direct and reliable detection of water and measurement of its abundance showed that water is by far the most abundant volatile material in Halley's nucleus, but this was not actually a new development, because so many lines of indirect evidence had overwhelmingly demonstrated the fact previously. On the other hand, prior to 1986, the canonical picture of cometary nuclei was that they were generally round and highly reflective, being covered primarily with ice. There had been several observations before Halley's latest apparition that indicated that some nuclei are dark, elongated, or both, but these observations had not affected the basic paradigm. The images of Halley's nucleus have totally changed the picture in everyone's mind. It is now widely accepted that cometary nuclei are very dark (reflectivity less than 5 percent) and quite elongated. In the absence of the pictures of Halley, this change would still have come about through Earth-based observations of a variety of short-period comets, but it would have come much more slowly. The pictures also provided the first evidence that convinced everyone that inert mantles developed on cometary surfaces, another concept that previously had been suggested from indirect evidence but that had not become part of the paradigm. A totally new idea, which was derived in large part from the results of the mass spectrometer, was that a large fraction of certain gases in the coma were not evaporated from the nucleus but rather were released from grains in the coma out to distances of 20,000 kilometers or more from the nucleus. There had been hints of this in earlier work, but this is now part of the paradigm and is invoked in all recent papers on the distribution of material in the coma. Finally, the discovery that the grains were of three chemically distinct types—silicates, "CHON," and mixed chondrites—was a dramatically new result.

On the other hand, other aspects of comets in general and of Halley in particular are still not understood. Despite direct images of the nucleus from three different spacecraft at three different times, scientists still have not reached full agreement on how to describe the rotational motion of Halley's nucleus. Earth-based and in situ measurements of the composition of the nucleus still disagree by an order of magnitude about the abundance of ammonia relative to water. This contrast between startling new discoveries that already have been absorbed into the common paradigm and ostensibly straightforward determinations on which we still cannot agree is in some ways the most intriguing result from the study of comet Halley.

Mason's two-volume work consists of a series of invited review papers covering most aspects of cometary science that were actively studied during the apparition of Halley's comet. There is a wide range of quality among the chapters, which run the gamut from summaries of the results obtained with a specific instrument on a single spacecraft to excellent syntheses of data relevant to a particular problem that place those data in a theoretical context.

Our understanding of comet Halley is still evolving, and a book can only reflect the state of our knowledge when each chapter was written. This point is specifically addressed by Sekanina in his chapter about the rotation vector of the nucleus in volume 2 of the work. He notes that the paper was written in 1987 but then was changed in several critical places in 1989 because some



"Photographs of comet Halley taken on 11 March 1987. Note that no distinct disconnection event was observed, even though the world-first *in situ* observation of the sector boundary was carried out only 1.8 × 10^6 km upstream of the comet." [From T. Saito's chapter in *Comet Halley: Investigations, Results, Interpretations*] of the previously accepted ideas about the rotation of the nucleus had been totally discarded by then. Papers being written in 1991 disagree with even the most recent papers available when Sekanina changed his chapter for the last time. By 1989, the "classical" 2.2-day periodicity, which had been derived in the early 1980s from images taken in 1910, was on its way out, and it was already clear that the motion was complex. Current papers suggest that the motion consists of 7.4-day and 3.7-day rotations around different axes, with a nodding motion about the third axis. Sekanina also reminds us of another puzzling aspect of the motion of Halley's nucleus: the images of the nucleus show strong jets of material ejected from the nucleus in such a way that they should produce significant torques. Simple calculations show that these torques could change the motion of the nucleus dramatically on the time scale of a month. Nevertheless, the variability in 1910 and the constancy of the rocket-like acceleration of Halley in its orbit (due to the outgassing over two millennia) strongly suggest that the torques have no significant effect on the rotation vector. This phenomenon is not understood.

Whereas Sekanina's chapter really brings home to the reader the way in which our fundamental ideas have changed and are still changing, other chapters are much less illuminating, and some are highly redundant. On the whole, the second volume is much better than the first, if for no other reason than that it contains some chapters devoted largely to theoretical work that provide a context for the experimental and observational results. Even the primarily observational chapters in this volume typically provide a certain amount of theoretical background, whereas in volume 1 a significant fraction of the chapters do not provide that context.

Some of the better chapters in volume 1 are the chapter on jets by Kömle and the chapter on chemical composition by Krankowsky and Eberhardt. Kömle discusses the theory of hydrodynamic flow from a nozzle and then discusses many different observations (both ground-based and from Giotto) of jets in Halley. He clearly illustrates the difficulty of reaching firm conclusions about the nature of the jet-like features observed. Krankowsky and Eberhardt have written a particularly valuable chapter in that they not only present their own data, which so dramatically show the existence of a distributed source of the carbon monoxide gas but also bring together many other measurements of the composition of the gas in the coma. They then put these pieces together to try to infer the composition of the nucleus. This chapter is fundamental to our basic understanding of comets and their origin, and I only wish that the authors had included more of their own results from the mass spectrometer on Giotto.

The work as a whole fails in its goal of presenting a clear comprehensive picture of our knowledge of comets, but it is valuable as a resource if read selectively and critically. Workers in the field will have other sources for even more details of the experiments and observations and will be able to go immediately to the chapters that bring together data from diverse sources. People outside the field may have to struggle to separate the wheat from the chaff.

MICHAEL F. A'HEARN
Astronomy Program,
University of Maryland,
College Park, MD 20742

Planetary Adventures

Uranus. The Planet, Rings and Satellites. ELLIS D. MINER. Horwood (Prentice Hall), Englewood Cliffs, NJ, 1990. 334 pp., illus. $59.95. Ellis Horwood Library of Space Sciences and Space Technology, Series in Astronomy.

"Much has been written about the Voyager missions, generally by authors far more eloquent and experienced in writing than I." So states Ellis Miner in the preface to his new and welcome book on NASA's highly successful Voyager mission to the outer planets. The statement, however, as the reader will quickly learn, is much more a reflection of the author's modesty than of the style and distinction of his writing.

The Voyager odyssey began with the launch of two robotic spacecraft, Voyagers 1 and 2, to the outer planets of our solar system in 1977. Voyager 1 flew past Jupiter in 1979 and Saturn in 1980 before leaving on a trajectory that is now taking it out of our solar system. Voyager 2 followed its predecessor both to Jupiter and to Saturn, then continued on to Uranus in 1986 and ended its planetary exploration at Neptune in 1989. Like its twin, Voyager 2 is now heading out of the solar system, while continuing to collect data on interplanetary and interstellar physics as it travels. The principal subject of Miner's book is the Voyager encounter with the planet Uranus, its rings, and its satellites, but the Voyager discoveries at Jupiter and Saturn are also well reviewed. Much of the effort committed to the preparation of this book apparently occurred at a time when Miner, the Voyager Assistant Project Scientist, was also deeply involved in preparing science activities for the upcoming encounter with Neptune, from which, regrettably, no results are included in the book.

The book begins with a well-documented history of both the discovery of Uranus and its discoverer, Sir William Herschel. This is followed by several chapters that summarize the more significant scientific knowledge of the Uranus system acquired by ground-based and airborne telescopes from the time of its discovery up to the end of the pre-Voyager era. Uranus is discussed in context with its outer solar system neighbors, giant planetary bodies with Earth-size cores of rock and ice, surrounded by deep atmospheres of hydrogen and helium. The next chapters are devoted to a history of the Voyager project, including key personnel, descriptions of the spacecraft themselves, in-flight problems, and a review of some of the more important discoveries made by both spacecraft at Jupiter and Saturn.

The second half of the book discusses in detail the many and exciting scientific accomplishments of Voyager at Uranus. Miner leads us through the preparation for the Uranus encounter, recounting the anticipated engineering problems involved in operating a spacecraft nearly 3 billion kilometers distant and reviewing the scientific objectives and the observational sequences that could best achieve them. He reviews the Voyager results, which include data on the planet itself, including internal mass distribution, thermal properties, atmospheric structure, and wind profiles; the magnetic field and magnetosphere, along with plasma and high-energy charged particle environments; the physical and photometric properties of the ring system, including several previously unknown features; the physical and geological properties of the five major Uranian satellites and the ten new moons discovered by Voyager. Uranus is found to be a distinctly individual planet, with many of its characteristics uniquely different from its giant planet neighbors.

Each chapter of *Uranus* is complete with thorough notes and references and bibliography. Illustrations and diagrams are of high quality and have been well chosen to complement the text. Errors are few, but Miner's continued use of somewhat obscure names for certain stars, such as Rigel Kentaurus for α Centauri, brought back humorous memories of us astronomers scurrying for our handbooks whenever Miner and his engineering colleagues would update the current stars being recommended as targets for spacecraft stability guidance.

The Voyager discoveries have completely revised our scientific understanding of the outer solar system, a vast, remote region that includes more than 99 percent of all known