accurate (to 10-cm wavelength) surface for his planned 21-cm line research program. He embarked on an extensive galactic structure program when the telescope became operational in 1962. In 1966, he left Australia to join the University of Maryland, College Park, as a visiting professor of astronomy. He then became a professor of astronomy in 1968, a position he held until his retirement in 1987. But Frank did not lose interest in the Southern Hemisphere. In 1968 and 1970, he traveled to Argentina, where he amazed local astronomers with his tenacious observing. And during the 1970s, Frank and some of his students went to Australia to make a complete 21-cm survey along a 20-degree strip of the Southern Milky Way. Between 1986 and 1990, Frank successfully searched for evidence of galaxies hidden behind the Milky Way dust, and thus opened up a new and active field of research.

Frank served astronomy in many capacities: He was the chairman of the NSF advisory panel on astronomy (1971–72); director of the University of Maryland astronomy program (1973–78); councilor of the American Astronomical Society (AAS; 1972–75); and president of IAU Commission 33 (1976–79). He also was provost of the University of Maryland physical and mathematical sciences and engineering division (1978–85); AAS vice president (1980–82); chair of an IAU working group that recommended new standard values for the size and rotation properties of the Galaxy (1982–86); director of the Universities Space Research Association (USRA) astronomy and space physics division (1983–95); and chairman of the USRA Council of Institutions (1984–85).

Frank was a leader, adviser, innovator, and mentor for his scientific colleagues around the world and an outstanding source of ideas. He was a renaissance man with a pleasant, self-effacing disposition belying his enormous stature.

Gart Westerhout
Baltimore, Maryland

John Aloysius O'Keefe

John Aloysius O'Keefe, a man considered to be the father of space geodesy, a pioneer in planetary physics, and a longtime student of tektites, died in Sioux Falls, South Dakota, on 8 September 2000, of liver cancer complicated by Parkinson's disease.

O'Keefe was born in Lynn, Massachusetts, on 13 October 1916. He graduated from Harvard University in 1937 with a bachelor's degree in astronomy and received his PhD in astronomy from the University of Chicago in 1941. His first major discovery (in 1938) was that clouds of solid carbon cause the peculiar dips in the light curve of R Coronae Borealis, the archetype of a class of carbon-rich stars.

With the advent of World War II, O'Keefe was rejected for military service because of a physical disability. Instead, he joined the US Army Corps of Engineers as a civilian and began a new career as a geodesist, producing improved maps for the war effort. In 1945, the Army Map Service was formed to carry out the COE's mapping and geodetic missions. That same year, O'Keefe was appointed to head the research and analysis branch, where he was responsible for geodetic R&D. During the 13 years he held this post, he not only made significant individual contributions to geodesy, but was a mentor who inspired his staff members.

As an astronomer, O'Keefe felt the lure of the space program. He left his position at the Army Map Service in 1958 to become the assistant chief of the theoretical division at NASA's newly formed Goddard Space Flight Center in Greenbelt, Maryland, where he spent the rest of his career. Some of O'Keefe's most influential early work at Goddard was behind the scenes. Eugene Shoemaker christened him "the godfather of astrogeology" for services on behalf of the Apollo program and especially for his key role in expanding the scope of the US Geological Survey to include other celestial bodies.

However, O'Keefe is probably best remembered for one of the very first scientific results of the space age. After analyzing the orbit of Vanguard I, only the second satellite launched by the US, O'Keefe and his coworkers announced in 1959 that Earth's gravitational field perturbed the satellite's trajectory beyond what was expected from a rotationally flattened planet; Earth showed a surprising lumpiness in the Southern Hemisphere. O'Keefe's finding, dubbed the "pear-shaped Earth," made the newspapers and even became the subject of one of Charles M. Schulz's *Peanuts* comic strips.

In 1955, two years before Sputnik was created, O'Keefe proposed that geodesists track the motion of satellites for geodetic purposes. He intended to illuminate satellite-based

John Aloysius O'Keefe

retroreflectors with Earth-based searchlights. With the invention of the laser, optical tracking became feasible, and he strongly supported putting retroreflectors on satellites and on the lunar surface. At present, the LAGEOS (LAser GEOdynamic Satellites), STARLETTE, and similar retroreflector-bearing satellites measure plate motion, the Chandler wobble, and other geodynamic phenomena, and the retroreflector arrays the Apollo astronauts left on the Moon still bounce back laser beams shot from Earth. The lunar arrays have been used to test the theory of relativity.

During the last 30 or more years of his career, O'Keefe focused on the study of tektites, small glassy bodies of natural but unknown origin found in various "strewn fields" on Earth. In the 1950s and early 1960s, the leading theories were that tektites were of lunar origin, ejected by either impacts or volcanism, or they were formed by large asteroid impacts on Earth. O'Keefe published two books and many papers on the subject, and became convinced that tektites were ejected from volcanoes on the Moon.

However, since the late 1960s, scientists who have studied tektites have pointed to evidence that overwhelmingly suggests they were created as melt droplets from the impact of comets or small asteroids on Earth. O'Keefe's decades-long advocacy for a lunar origin saddened and sometimes angered many of his colleagues in the tektite community. On the program at his funeral, his family had included the words "Tektitae de luna sunt," which means "Tektites are from the Moon.

O'Keefe was endowed with a brilliant mind and a sharp wit. An innovative thinker, he possessed a contagious enthusiasm that often exceeded conventional bounds. He was a superb lecturer; his presentations frequently were flamboyant, giving rise to numerous amusing anecdotes among his associates. Above all, O'Keefe followed the dictates of his conscience in determining his actions. His colleagues remember him not only as an exceptional scientist, but as a remarkable person.

DAVID P. RUBINCAM
PAUL D. LOWMAN
NASA's Goddard Spaceflight Center
Greenbelt, Maryland
BERNARD CHOVITZ
Chevy Chase, Maryland

Lev Pavlovich Rapoport

LEV PAVLOVICH RAPOPORT

Lev Pavlovich Rapoport, who headed Voronezh State University's school of theoretical physics for more than 40 years, died of bladder cancer in Voronezh, Russia, on 15 September 2000. Rapoport was well known for his pioneering works in nuclear and atomic physics.

Rapoport was born on 13 January 1920 in the small town of Usman' in the Lipetsk region of Russia. After studying in a school for pilots from 1937 to 1940, he entered Moscow's Institute of Aviation in 1940, but never completed his schooling there because of the German invasion of 1941. He was evacuated to the Siberian city of Irkutsk, where he worked until the end of World War II in an aviation plant as a technician.

In 1946, Rapoport entered Voronezh State University; he received his diploma in physics in 1948. He received his PhD degree in physics in 1951. His doctoral thesis, written under the supervision of Maria A. Levitskaya, the first professor of physics at Voronezh State, was on gamma and beta processes in atomic nuclei. Rapoport spent the remainder of his career in Voronezh State University's department of theoretical physics. (Note that, in Russia, a "school of theoretical physics" refers to a group of individuals who received their PhDs in theoretical physics from one and the same professor, who initially headed the department of theoretical physics.) He was an assistant professor (1952–56); chair (1956–93); and full professor (from 1971 until his death). During the reconstruction period following World War II, Rapoport taught nearly all the basic courses in theoretical physics and developed most of the department's elective courses.

Rapoport's scientific achievements spanned a wide range of physics. After becoming a well-known specialist in theoretical nuclear physics during the 1950s, he published works in the then-new fields of superfluidity and superconductivity in the early 1960s. He gave a generalization of the Landau–Ginzburg equations applicable for lower temperatures and proposed a microscopic theory of magnetic flux quantization in superconductors. He also contributed to the development of the theory of finite Fermi systems, which he applied to the nuclear processes of beta decay and electron capture. In this work, the Green's function method formed the basis for numerical calculations.

The Green's function method also proved exceptionally fruitful in solving a problem that had taken on great importance by the late 1960s: the behavior of atoms and molecules in high-intensity laser fields. From that time until the end of his career, Rapoport was committed to studying this behavior. His first works in this field concerned the simplest of atoms, atomic hydrogen, and, more specifically, light scattering from, and two-photon ionization of, hydrogen atoms. His analytical calculations of the cross sections for those processes are now considered classic works, and the methods he used to derive the corresponding formulas have formed the basis of many subsequent theoretical works by researchers both in Russia and abroad. Further modifications of the Green's function method enabled researchers to study multiphoton processes in many-electron atoms and in simple molecules and also made possible numerical calculations of higher-order relativistic effects in