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GERARD PETER KUIPER

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A Biographical Memoir by

DALE P. CRUIKSHANK

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Photograph by Dennis Milou

Gerard P Kuiper

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BY DALE P. CRUIKSHANK

HOW DID THE SUN and planets form in the cloud of gas and dust called the solar nebula, and how does this genesis relate to the formation of other star systems? What is the nature of the atmospheres and the surfaces of the planets in the contemporary solar system, and what have been their evolutionary histories? These were the driving intellectual questions that inspired Gerard Kuiper's life of observational study of stellar evolution, the properties of star systems, and the physics and chemistry of the Sun's family of planets.

Gerard Peter Kuiper (originally Gerrit Pieter Kuiper) was born in The Netherlands in the municipality of Haringcarspel, now Harenkarspel, on December 7, 1905, son of Gerrit and Antje (de Vries) Kuiper. He died in Mexico City on December 24, 1973, while on a trip with his wife and his long-time friend and colleague, Fred Whipple. He was the first of four children; his sister, Augusta, was a teacher before marriage, and his brothers, Pieter and Nicolaas, were trained as engineers. Kuiper's father was a tailor.

Young Kuiper was an outstanding grade school student, but for a high school education he was obliged to leave his small town and go to Haarlem to a special institution that would lead him to a career as a primary school teacher.

The path to a university education in Holland was normally through proper high schools for that purpose, but Kuiper was intent on university admission and passed an especially difficult special examination that allowed him to enter Leiden University. In the same year, he passed an examination for certification to teach high school mathematics. Kuiper's, drive, persistence, and self-assurance, already well developed in his student days, moved him to succeed in spite of an atmosphere of discrimination at Leiden against poorer students and those who had not studied in the proper high schools.

At a young age, Kuiper's interest in astronomy was sparked when he read the philosophical and cosmological writings of Descartes. This interest was encouraged by his father and his grandfather, who gave him a small telescope. With his naked eye, Kuiper made sketches throughout an entire winter to record the faintest members of the Pleiades star cluster that he could detect. On his master chart, Leiden Observatory astronomers, to whom he sent the results, found the limiting magnitude 7.5, nearly four times fainter than those visible to the normal human eye. Even in his later years, Kuiper's visual acuity was exceptional.

Kuiper entered Leiden University in September 1924. His fellow student and long-time friend Bart J. Bok recalled the day they met as incoming students in the library of the Institute of Theoretical Physics. Kuiper explained to Bok that he intended to pursue astronomical problems of a fundamental nature, specifically the three-body problem and related questions about the nature and origin of the solar system. He completed a B.Sc. at Leiden in 1927 and immediately went on to postgraduate studies. Among Kuiper's professors at Leiden were Ejnar Hertzsprung, Antonie Pannekoek, and the theoretical physicist Paul Ehrenfest.

Kuiper became a friend of the Ehrenfest family in his role as tutor to the physicist's son.

Kuiper, Bok, and fellow student Piet Oosterhoff pursued their studies in astronomy together, learning from Willem de Sitter, Jan Woltjer, and Jan Oort, in addition to those named above. In his student years, Kuiper joined the Dutch solar eclipse expedition to Sumatra for eight months in 1929. He learned Malay and wandered among the native villages painting beach scenes and studying the local customs. Then, on the eve of the eclipse he discovered that another astronomer had incorrectly oriented the spectrograph slit on one of the cameras; the correction was made just in time to secure important data during the eclipse the next day.

In 1929, Kuiper began correspondence with the great double-star astronomer Robert Grant Aitken, at Lick Observatory of the University of California, and submitted his earliest measurements for criticism. He also outlined for Aitken the essence of the statistical study which was to occupy him for over a decade. Kuiper did his doctoral thesis on binary stars with Hertzsprung, and he received his Ph.D. on completion of this work in 1933. That same year he traveled to the United States to become a Kellogg Fellow (and then a Morrison Fellow) at Lick Observatory near San Jose on Mount Hamilton.

Under Aitken's tutelage, Kuiper continued his work on binary stars at Lick, where he systematically examined stars of large parallax for duplicity. He had delayed publication of his thesis until he could improve the observational data for double stars with large differences in brightness between the components. Observing visual doubles with the 12- and 36-inch refractors and making color-index measurements with the Crossley 36-inch reflector, he discovered numerous binaries and many white dwarf stars.

Kuiper always considered himself a double-star astronomer, and he was strongly influenced by Aitken. Aitken had learned from E. E. Barnard, and he in turn had learned the art from the great S. W. Burnham.

Concerning this work, in 1971 Kuiper recalled that at the beginning of his career he had been asked to review a book on the origin of the solar system.

> The analytical part of the book impressed me greatly. The second, synthetic part was entirely disappointing. After the review was written, I continued to struggle with this problem and had to conclude that the state of astronomy did not permit its solution. . . . I then determined to find a closely related problem, that with finite effort would probably lend itself to a solution . . . the origin of double stars.[1]

Eventually, Kuiper announced that at least 50 percent of the nearest stars are binaries or multiple-star systems. He more clearly defined the mass-luminosity relation for main-sequence stars and showed that the white dwarfs are high-mass objects departing from the empirical law. His 1938 paper in the *Astrophysical Journal* on the mass-luminosity relation is still considered a standard work on the subject.

Though intellectually stimulating and productive, the two years at the Lick Observatory were not an unqualified success. Sensitivities in the small, remote mountaintop community of astronomers were acute, and Kuiper was perceived by some as talented but somewhat outspoken and abrasive. He was not to become the heir to Aitken's legacy, and in August 1935 he left for a year at Harvard College Observatory.

At the time he arrived in Cambridge, Kuiper intended to go to Java to continue his career at the Bosscha Observatory. Instead, he met and married (on June 20, 1936) Sarah Parker Fuller, whose family had donated the land on which Harvard's Oak Ridge Observatory is built. During that year he was offered a position at the Yerkes Observatory of the University of Chicago by the director, Otto Struve. In November 1935, Kuiper telegraphed to Java that he would decline the position there. Kuiper felt that he could make an important contribution to astronomy by moving to Yerkes, but lamented in a letter to W. H. Wright of Lick Observatory (October 30, 1935) that ". . . it will mean a real sacrifice to me not to go to the beautiful and happy island of Java." In fact, he might not have been able to escape the Japanese prison camps after the invasion a few years later.

Even before Kuiper moved to Yerkes, Struve sought his advice on matters related to the addition of new senior staff members at that institution. In 1936 Kuiper was appointed assistant professor at the University of Chicago. He was associate professor from 1937 to 1943 and was then appointed professor.

As a new staff astronomer at Yerkes, Kuiper contributed heavily to what W. W. Morgan has called the renaissance of the Observatory. That rebirth was initiated by Struve, who, as the new director from 1932, brought Kuiper, S. Chandrasekhar, and Bengt Strömgren to the staff; Morgan was a graduate student there and was appointed instructor in 1932. Bok has noted that Kuiper's marriage and appointment at Yerkes Observatory were strong positive stimuli to his scientific work in the late 1930s and 1940s.

In his new post Kuiper worked with Struve and Strömgren on the eclipsing binary Epsilon Aurigae, proposing in a major joint paper in 1937 that a large star surrounded by a partly transparent gas halo eclipses an F supergiant whose ultraviolet radiation has ionized part of the larger star's tenuous atmosphere. This model spawned numerous additional observational and theoretical studies of the unique Epsilon Aurigae system.

To determine evolutionary tracks in the Hertzsprung-Russell temperature-luminosity diagram, Kuiper combined Strömgren's theoretical studies with Robert Trumpler's observations of clusters. In 1937, Kuiper published in the *Astrophysical Journal* a historic color-magnitude diagram for galactic clusters, interpreting the tracks shown as Strömgren's lines of constant hydrogen content and pointing out that this hypothesis explains several other observational results. The next year he derived the corrections needed to convert photographic stellar magnitudes, providing the basis for the stellar temperature scale that was in wide use until the advent of ultraviolet satellite astronomy.

Kuiper joined Struve and other members of the Yerkes staff in planning for the University of Texas 82-inch reflecting telescope, to be operated jointly by Yerkes and the University. McDonald Observatory near Fort Davis, Texas, was dedicated in 1939, and with the new instrument and its high-quality spectrographs, Kuiper continued his search for white dwarfs and spectroscopic studies of stars with large proper motions. He took up residence at the remote observing site in west Texas during the breaking-in period of the 82-inch telescope and began to acquire data on stars that had been too faint for the telescopes previously available to him. Although life at the remote and poorly developed observatory site was a strain on his family, the McDonald telescope was at that time the second largest in the world and a vital tool for the work he had set out to accomplish.

An early target of Kuiper's new work was Beta Lyrae. In his monumental 1941 paper on this double-star system, Kuiper introduced the term "contact binaries." In this work he also recognized that material accreted by the smaller star would form a ring around it; he thus anticipated the accretion disks of mass-exchange binary stars that are now known to be of great importance.

During World War II (1943 to 1945), Kuiper took a leave of absence from the University of Chicago and joined the faculty of Harvard's Radio Research Laboratory, where he was involved in radar countermeasures. In this connection he went to England with the Eighth Air Force Headquarters in 1944. He returned to Europe in January 1945 as a member of the ALSOS Mission of the U.S. War Department, to assess the state of German science. Kuiper accomplished a rather daring rescue of Max Planck, who he learned was in the eastern zone of Germany in dire circumstances and in danger of being captured by Soviet troops. He took a vehicle and driver and raced across the countryside to Planck's location, arriving only hours ahead of the Soviets. Planck and his wife were taken to the western zone and then on to Göttingen and to the care of friends and relatives.

During a brief respite from war work in the winter of 1943–44, Kuiper returned to McDonald Observatory and included in his observing program a spectroscopic study of the major planets, the Galilean satellites of Jupiter, Triton, and four of Saturn's satellites, including Titan. He found the 6,190-angstrom band of methane in Titan, the first detection of an atmosphere on a satellite. In 1944 he wrote, "It is of special interest that this atmosphere contains gases that are rich in hydrogen atoms; such gases had previously been associated with bodies having a large surface gravity."

Concerning the discovery of Titan's atmosphere, Kuiper noted in a letter to J. H. Moore (February 29, 1944), then director of Lick Observatory, "The only reason I happened to observe the planets and the 10 brightest satellites was that they were nicely lined up in a region of the sky where I had run out of program stars (stars of large proper motion and parallax)."

While the discovery of Titan's atmosphere may have been serendipitous, it stimulated the studies of planetary atmospheres which were to occupy Kuiper until the end of his life. His interest was further stimulated by contacts with Bernard Lyot in France during and just after the war, whence he brought back reports of excellent planetary work in progress at Pic du Midi Observatory. Kuiper was greatly impressed with the heroism of the French astronomers during the occupation and wrote of this in news notes to astronomical journals. In 1947, he was awarded the Janssen Medal of the Astronomical Society of France. In Germany following its surrender, Kuiper learned from German scientists details of the new lead sulfide infrared detectors being developed on both sides during the war, and he was impressed by their astronomical possibilities. The American detectors were declassified in September 1946, and Kuiper soon collaborated with the detector's developer, Robert J. Cashman, on construction of an infrared spectrometer for the study of stellar spectra in the wavelength region of 1–3 micrometers.

Kuiper's first near-infrared spectra of stars and planets, made with a two-prism spectrometer later the same year, were of low resolution, but they laid the groundwork for the study of planetary atmospheres for the next quarter of a century. Between 1946 and the 1980s the near-infrared spectral resolution increased more than 100,000-fold, with a corresponding improvement in knowledge of planetary and stellar atmospheres. Kuiper's earliest spectra in 1947 revealed carbon dioxide on Mars. He was the first to see the near-infrared spectra of Jupiter and Saturn, as well as those of the Galilean satellites of Jupiter and the rings of Saturn. His intuitive interpretation has largely been borne out as the data have since improved.

At the fiftieth anniversary of Yerkes Observatory in 1947, Kuiper organized a symposium on planetary atmospheres, assembling astronomers, meteorologists, and other specialists for the first meeting of its kind. An important outcome was the book edited by Kuiper, *The Atmospheres of the Earth and Planets* (Chicago: University of Chicago Press, 1949 and 1952). In his own classic paper, Kuiper summarized knowledge of the composition of planetary atmospheres, presenting a lucid account of their origins as primary (in the case of the Jovian planets) or secondary (the terrestrial planets) gas envelopes with regard to their interaction with the early solar wind (though the term "solar wind" had yet to be invented). From combined spectroscopic and thermal measurements, he gave the first interpretation of the atmospheric structures of Jupiter and Saturn.

Kuiper was among the first to think of planetary phenomena in terms of cosmochemistry, a subject that has been greatly developed in recent years. His table of atmospheric compositions of the planets in the Yerkes symposium volume has been the foundation of much subsequent theoretical and observational work. To this day, improved visible, infrared, and ultraviolet spectra are used to refine Kuiper's abundance estimates, lower the detection limits, and reveal new gases in the atmospheres of the planets.

Kuiper typically worked alone up to this time; according to Bok, he was too busy to work with students. With his own energetic self-motivation, and in the atmosphere of selfless service to science inspired by Otto Struve at Yerkes, Kuiper worked with great intensity on his science and in influencing the directions of the Yerkes and McDonald observatories. In the mid-1940s, however, Kuiper's work attracted Daniel E. Harris III, who was to become his first student of planetary astronomy. They collaborated on photometric studies of planets, satellites, and asteroids, and in 1949 Harris completed his Ph.D. work with a dissertation on the satellite system of Uranus. (Harris died prematurely on April 29, 1962.) In February 1948, Kuiper found and named a fifth satellite (Miranda) of Uranus on photographs taken to determine relative magnitudes of the four known satellites. In a systematic search for outer and inner satellites of the planets, he found Nereid, the second moon of Neptune, in May 1949.

Succeeding his long-time friend Otto Struve, Kuiper became director of Yerkes and McDonald observatories in 1947, a post he occupied for two years and then resumed in 1957. His thoughts were returning to the origin of the solar system, as he described in the Kepler Medal discourse in 1971:

> I felt that I had come to understand the problem of double-star origin, at least in outline; that it was identical to the general process of star formation, from slightly turbulent prestellar clouds upon contraction, with conservation of angular momentum. It followed that the Solar System was no more than an "unsuccessful" double star with the companion mass spread out radially into a disk that in time developed the planets. . . . The *mass partition* between [the primary and companion masses] would be random mass fractions of the total, a result I had derived empirically from a statistical study of double-star ratios. Thus, planetary systems clearly had to originate as the low-mass extremity of the almost universal process of double-star formation. . . . A basis had thus been found for estimating the *frequency* of planetary systems in our galaxy.

In September 1949, Kuiper startled his colleagues and the public with the announcement that the frequency of planetary systems was at least one in a thousand. A year or two later he revised this to be at least one in a hundred, and then as many as half of the total number of stars in the galaxy; earlier workers had considered planetary systems extremely rare, perhaps one in a trillion stars.

That same year, Kuiper organized and initiated the Yerkes-McDonald asteroid survey, in order to provide reliable statistical information on the asteroid population down to magnitude 16.5. The main results from over 1,200 photographic plates were published in 1958, with one of the authors being Kuiper's second student of the solar system, fellow Dutchman Tom Gehrels. Gehrels had been given a student assistantship in 1952 with the formidable task of determining the brightnesses of the asteroids on the huge volume of photographic plates taken at McDonald Observatory. This work was the precursor to the later Palomar-Leiden survey to magnitude 20.5, from which essential statistical information on the asteroid population was derived.

By early 1950, Kuiper developed a theory of the origin of the solar system. In 1945, G. Gamow and J. A. Hynek had called the attention of American astronomers to a significant new work on this topic published a year before by C. F. von Weizsacker in war-torn Germany. Attracted by von Weizsacker's quantitative revival of the solar nebula theory of Descartes and Kant, and apparently influenced by the work of H. P. Berlage and D. ter Haar, Kuiper extended the work, arguing that large-scale gravitational instabilities could occur in the rotating solar nebula; these regions would be stable against the tidal shear by the Sun, and the material in them could begin to condense. The large condensations eventually became the protoplanets, of which there was one for each of the present planets formed in the central parts of the condensations, with satellites in the extremities. Uncondensed gas, constituting the majority of the initial mass of the protoplanets, was dissipated to the outer parts of the nebula by the solar wind. Except for the important role played by the solar wind, the Kuiper theory is basically a gravitational one in which angular momentum is lost by conventional means; more recent theories have shown that other mechanisms, such as magnetic and electrical fields, are needed to transfer momentum in the contracting and rotating nebula.

Kuiper recognized that certain satellites and some classes of asteroids did not fit the simple picture he had outlined, and in a lengthy series of papers published between 1950 and 1956 he explored the oddities of the solar system, the irregular planetary satellites, the Trojan asteroids, the comets, Pluto, the Earth-Moon pair, and other objects in an effort to understand their origins and their dynamical evolution.

The problem of the origin of the solar system attracted many investigators in the 1950s and 1960s, eventually leaving Kuiper's gravitational theory largely behind. It was with great delight that he returned to the subject in 1972, with a major work only partly finished and published at the time of his death.

In the course of his development of the theory of the solar system, Kuiper took a serious interest in the surface of the Moon, recognizing the information it contains for the early dynamic history of the terrestrial group of planets. Some early results of his careful visual and photographic observations of the Moon with the McDonald 82-inch telescope are interpreted in a series of papers in the *Proceedings of the National Academy of Sciences* (he had been elected a member of the Academy in 1950). Kuiper's interest in the Moon had been kindled in part by the appearance in 1949 of R. B. Baldwin's book *The Face of the Moon,* for which he often expressed great admiration. His studies of the time scale of formation on the lunar surface features attracted wide attention and generated a heated debate with Harold Urey in the pages of the *Proceedings.* For the next fifteen years, Kuiper would frequently defend his often rigidly held theories of the lunar surface in public and professional forums.

When Strömgren resigned as director of Yerkes and McDonald observatories in 1957, Kuiper was elected to the position for a second time, and it was in the next year, as a summer assistant at Yerkes, that I had my first contact with him. By that time he had begun work on a contract with the U.S. Air Force to produce an atlas of the best available photographs of the Moon selected from the collections at Lick and Mt. Wilson Observatories, augmented by Kuiper's own McDonald photographs. Soon thereafter, he invited the British lunar specialists E. A. Whitaker and D. W. G. Arthur to join him for continued work in selenodesy, lunar cartography, and photogrammetry. The *Photographic Lunar Atlas*, published in 1960, was the magnificent product of the enormous effort invested by Kuiper and his collaborators.

During this second period of Kuiper's directorship at Yerkes, his third student of planetary science, Carl Sagan, completed his graduate work at the University of Chicago.

Aware of the dearth of comprehensive literature on the physics of the solar system in the 1950s, Kuiper organized a large editorial project to produce four encyclopedic volumes on the Sun, the planets, the Earth as a planet, and the satellites and comets. The first, *The Sun*, was published in 1953, and the last, *The Moon, Meteorites and Comets*, was published ten years later. While still at Yerkes, he organized the production of a more comprehensive nine-volume compendium, *Stars and Stellar Systems.* Much of the work on these books was accomplished by Barbara Middlehurst, who had joined Kuiper as an associate editor.

With the new interest in the Moon on the part of the U.S. Air Force and the recently created (in 1958) National Aeronautics and Space Administration, Kuiper received substantial support and encouragement for his solar system studies. He also saw opportunities for further studies of the solar system with NASA support as plans were begun for the first deep space probes to the planets.

In late 1959, the Yerkes staff voted not to reappoint Kuiper director and chairman, and while the intent was that he would continue his three-year term to its end in August 1960, his directorship in fact was terminated in January 1960. The growing tensions among the senior staff eventually resulted in Kuiper's resignation from his professorship later in 1960, whereupon he relocated at the University of Arizona in Tucson.

What follows is my own view of the state of affairs, gleaned from conversations with those involved and those who viewed the situation from outside the Yerkes staff.

Otto Struve, the hard-driving and autocratic director of Yerkes Observatory, had assembled a staff of extraordinarily talented observational and theoretical astronomers and astrophysicists. The scientific output was at the highest intellectual level, and the students educated in the program at Yerkes in those days became the senior astrophysicists of the next generation. With the talent came strong personalities, and Kuiper was one of several whose native brilliance was accompanied by an uncompromising self-assurance of the importance of his own work. Struve had the ability to mold the Yerkes staff into a highly productive entity, but by the time he left in 1950, the binding had unraveled. Natural tensions among individuals with strong personalities and scientific territorial instincts began to rise, resulting in a situation widely referred to as a "civil war." Professional criticism of Kuiper among the Yerkes staff members arose in part because of his demanding personality, in part because of his well-known conflicts with certain astronomers elsewhere, and also because of his shift away from "classical" astrophysics to problems of the solar system. One illustrative conflict is that with another white dwarf star specialist and fellow Dutchman W. J. Luyten, of the University of Minnesota. Struve mediated between Kuiper and Luyten in their proprietary conflicts over white dwarf stars to the extent that a written pact of collaboration drawn up by Struve was signed by the belligerent parties. When Kuiper shortly thereafter published a paper that Luyten considered a violation of the pact, Luyten tore up his copy of the document.

In the late nineteenth century, the study of the planets was a significant part of the work of most observatories in America and abroad. An element of fantasy entered this work with the publicity and voluminous popular writing about the canals of Mars, largely by Percival Lowell in the United States and Camille Flammarion in France. The popularity of the space-related science fiction of Jules Verne and others also contributed to the perception of many professional astronomers that the study of the planets was outside the realm of serious astrophysics. Those very few astronomers who applied the developing observational techniques to the planets did so in a very low key throughout the first half of the twentieth century. It was Gerard Kuiper who endeavored to return the physical study of the solar system to respectability on the strength of his own reputation, previously established in stellar studies, and through application of infrared techniques to the study of planetary atmospheres.

In 1960 Kuiper established the Lunar and Planetary Laboratory (LPL), first as an adjunct to the Institute of Atmospheric Physics and later as a separate entity of the University of Arizona. Kuiper conceived of the Lunar and Planetary Laboratory as a multidisciplinary approach to the study of the solar system, drawing upon astronomy, geology, atmospheric physics, and chemistry, all of which were well established at the University of Arizona. With this move, when he was fifty-four, his career accelerated to a most extraordinary pace. Many Yerkes staff members accompanied or ultimately followed Kuiper to Arizona. Whitaker, Arthur, Elliott Moore, Middlehurst, van Biesbroeck, and others were all at one time important members of the LPL staff. Four new students, Tobias C. Owen, William K. Hartmann, Alan B. Binder, and I, joined Kuiper's group in those first years in Tucson, all seeking an education in planetary studies and all going on to independent research after several years of association with him in Arizona.

With new developments in infrared detectors and diffraction grating technology, Kuiper's attention at once returned to stellar and planetary spectroscopy. By the end of the first year in Tucson, his group produced a new spectrometer with nearly 100 times the performance of the device used in his earliest infrared work. No time was lost in putting the new instrument to work on the McDonald 82-inch telescope and on the recently completed 36-inch telescope at Kitt Peak National Observatory. As he described in his summary of the first three years of LPL (*Sky and Telescope*, January and February 1964), the results were quick to follow: measurement of the isotopic ratios and the discovery of several "hot" bands of carbon dioxide on Venus, experimental verification of the low pressure on Mars, and detection of new absorption bands in the spectra of Alpha Orionis, Chi Cygni, and other cool stars. Later came the first observations of the infrared lines of hydrogen in the spectra of early-type stars. The cool stellar spectral bands were soon identified as carbon monoxide and, in the case of Omicron Ceti, water vapor.

From the beginning, Kuiper had emphasized laboratory studies of gases in long-path absorption cells as an essential part of planetary spectroscopic work, an approach clearly resulting from his association with Gerhard Herzberg at Yerkes in the late 1940s and early 1950s. The expanded LPL facilities included a 40-meter multiple-path cell, one of the largest in the world.

Shortly after he founded LPL, Kuiper began a search for high-quality sites for astronomical observatories especially suited to work in the infrared and on the planets. Together with Harold Johnson, who joined LPL in 1962, he established a family of telescopes in the Santa Catalina Mountains near Tucson. The major instrument was Kuiper's 61-inch NASA-funded telescope, put into operation in late 1965. The lengthy series of high-resolution planetary and lunar photographs initiated by Kuiper with this fine telescope include the best ever obtained from the ground.

In the early LPL years, Kuiper observed regularly at McDonald and Kitt Peak, made balloon spectroscopic observations of the Earth's atmosphere, and conducted observatory site surveys in Hawaii, Mexico, and California. He was influential in initiating what is now the Cerro Tololo Interamerican Observatory in Chile. It was largely his strong interest in 13,800-foot Mauna Kea in Hawaii as an infrared observing site that led to its development and the installation of a 2.24-meter NASA-funded telescope there in 1968; Mauna Kea now holds the largest collection of large telescopes in the world. He remained continuously engaged in the search for and study of superior observing sites, as he was in Mexico at the time of his death.

At LPL, the lunar work required a special effort with the interpretation of NASA's Ranger and Surveyor Moon probe results, which were precursors to the manned-landing program. The fundamental work on selenographic coordinates, *The Orthographic Atlas of the Moon,* done at Yerkes by Kuiper, Whitaker, and Arthur, was published in Tucson in 1960. In 1963 came the *Rectified Lunar Atlas,* during the preparation of which Kuiper and Hartmann discovered many lunar concentric basins and opened a new era of interpretation of early lunar impact history. Kuiper was principal investigator on the NASA Ranger program and served as an experimenter on the Surveyor program in the mid-1960s, eventually editing the voluminous photographic atlas of Ranger pictures. In 1967, Kuiper and his colleagues published an atlas of the best lunar photographs made from several ground-based observatories.

In addition to the special atlases published in Arizona, Kuiper had in 1962 begun publication of the *Communications of the Lunar and Planetary Laboratory*, an observatory annals-type journal which he edited and for eleven years used as his main line of communication to the astronomical community.

Kuiper took a keen interest and played an influential role in the development of infrared astronomy in the 1960s. In 1967 the NASA Convair 990 aircraft with a telescope aboard became available for infrared studies from an altitude of 40,000 feet, and Kuiper at once began observations of the planets and stars. In 1967 and 1968, he conducted a program to make an atlas of the infrared solar spectrum at high resolution above most of the atmosphere. The atlas was published in ten articles in the *Communications.* In recognition of the impetus he provided to airborne infrared astronomy, the successor to the Convair 990 ("Galileo"), a 1-meter telescope in a C-141 aircraft, was named the Kuiper Airborne Observatory in 1975.

Throughout the Arizona years, Kuiper served on NASA committees and panels, and he briefed high government officials on aspects of the space program. His scientific input to NASA officials at many levels influenced the course of ground-based and space probe investigations of the solar system.

Kuiper had a remarkable ability to recognize opportunities for advances in astronomy afforded by the development of new instruments and techniques. Seeing an opportunity for an advancement in astronomy, Kuiper would seize upon it and push it to a self-sustaining degree of development, using all his prodigious energy.

As an observer, Kuiper was indefatigable. I accompanied him as a student assistant on many long observing runs at McDonald and Kitt Peak observatories in the 1960s when the full nighttime schedule of infrared spectroscopy was supplemented by daytime observations of bright stars and planets. During these periods, sometimes amounting to fourteen consecutive clear days and nights at McDonald, Kuiper would function on three to four hours of sleep on some days, while another assistant and I would work ten-hour shifts. When heavily fatigued at some time during the day or night at the telescope, he would occasionally lie down on the observing platform only to awaken twenty minutes later appearing fully refreshed and ready to press on for another four to six hours. In retrospect, it seems not at all surprising that Kuiper independently discovered Nova Puppis visually, *after* completing a full night's observing (in November 1942), or that he then reopened the telescope and obtained four spectra and a position determination before the Sun rose.

Gerard Kuiper was a demanding individual who thrived on a daily routine of hard work and long hours, and he expected the same from his subordinates and associates. His European formality both attracted and repelled many of the people with whom he had contact. He was in complete command of his manner, which was by nature outwardly kind and friendly, though reserved and serious. But he could become instantly cool and acerbic in some unpleasant confrontation, which he greatly disliked and carefully avoided whenever possible. He sought loyalty in his associates, and in return his sense of fair play prevailed in his supervisory capacity as director at Yerkes and LPL. However, as an intensely driven man, Kuiper's perceived hauteur occasionally strained the patience and loyalty of his colleagues and friends.

Two children were born to Gerard and Sarah Kuiper, Paul Hayes in 1941 and Sylvia Lucy Ann in 1947. Both grew to become intelligent, talented, and perceptive adults in the loving household that was the rock of stability in Kuiper's personal life.

Kuiper had a delightful eagerness to share his knowledge and perceptions, a fact that many anecdotes could substantiate. He had a strong aesthetic sense, and on the numerous topics of interest to him Kuiper was a marvelous conversationalist, with a ranging curiosity and a perceptible wit. He commanded wide respect for his achievements, his organizational abilities, and his passion for science. His gift of prodigious energy was matched by one of acute intuition. Kuiper's approach to science was, in fact, highly intuitive, propelled by first-order computation from the first principles of physics, and always a drive for new data.

As an individual who initiated physical studies of the solar system, sometimes in the face of professional criticism, Gerard Kuiper can truly be considered the father of modern planetary astronomy. At the same time, his contributions to stellar astronomy remain a fundamental part of the literature of double-star studies, the nature and statistics of white dwarf and high-proper-motion stars, and infrared stellar spectroscopy.

SOURCES

The principal archive of Kuiper's correspondence, papers, and notebooks is held at the University of Arizona in Tucson. His correspondence and papers related to the years at Yerkes and McDonald observatories are located in the Archives of the Yerkes Observatory, Williams Bay, Wisconsin, while certain early letters are contained in the Mary Lea Shane Archives of the Lick Observatory, University of California, Santa Cruz.

THIS BIOGRAPHICAL MEMOIR is based in part on my article about Kuiper in *Sky and Telescope* 47 (1974):159–164. In preparing this memoir, I have benefited from interviews and correspondence with the late Bart J. Bok, Martin Schwarzschild, E. A. Whitaker, Donald M. Hunten, W. J. Luyten, S. Chandrasekhar, J. Oort, W. W. Morgan, and especially Tom Gehrels. Numerous colleagues and students of Kuiper commented on early drafts. I thank Mrs. Sarah F. Kuiper Lansberg for her friendship, interest, and support in the preparation of this memoir.

NOTE

1. Quotation from Kuiper's address on December 28, 1971, when he received the Kepler Gold Medal at a joint meeting of the American Association for the Advancement of Science and the Franklin Institute. For the full text, see *Communications of the Lunar and Planetary Laboratory* 9(1972–73):403.

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