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LYMAN SPITZER JR.
1914—1997

A Biographical Memoir by
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Photograph by Orren Jack Turner.

Lyman Spitzer, Jr.

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One of the leading theoretical astrophysicists of the 20th century, Lyman Spitzer showed a renaissance or even a classical figure in both his character and personal style. I once speculated that a biographer would someday remark on the importance of Spitzer's early exposure to ancient literature, and his family assured me that he had been, in fact, throughout his life strongly influenced by classical, especially Latin, models. If ever I have known an individual who fit the renaissance ideal of the gentleman scholar (based, of course, on earlier Latin archetypes), it was Lyman. The upright bearing, courteous speech, clarity, and total independence of mind were the dress of a person seemingly dropped into our midst from another age. Born in 1914 into a prosperous Toledo, Ohio, commercial family, he later married into the local, still wealthier clan of the Canadays. After Scott High School in Toledo and then Phillips Academy, Andover, Massachusetts, he received his B.A. at Yale in 1935, went to Cambridge University for a year (1935-1936), and there he was influenced by Arthur Eddington and Subramanian Chandrasekhar (an almost contemporary). Returning to the United States, he received his Ph.D. at Princeton under the legendary Henry Norris Russell (in 1938). Spitzer then went briefly to Harvard as a postdoctoral fellow, followed by a move to Yale, where he was appointed as instructor in 1939. It was shortly after moving to Yale that he married Doreen D. Canaday, herself a Bryn Mawr graduate, a totally charming and strong-willed woman with whom he raised a family of four children born between 1942 and 1954: Nicholas C., Dionis C., Sarah L., and Lydia S.

With the outbreak of World War II, Spitzer took leave from Yale to conduct scientific work in support of the war effort, initially as a member of the Special Studies Group at Columbia, then as director of the Sonar Analysis Group (at age 30). Radar was the major British technical contribution to the Allied war effort. While Lyman was always modest about the development, sonar along with the much more recognized A-bomb effort was one of the decisive technical contributions to the U.S. war machine. After the war, he returned briefly to Yale as associate professor (1946-1947). Spitzer then returned to Princeton University as professor in the spring of 1947, at the age of 33, succeeding Russell as chair of the Department of Astronomy and director of Princeton University Observatory. The scientific program of Princeton University Observatory, initiated in 1947 by Spitzer along with his contemporaneous colleague Martin Schwarzschild, was maintained as a leading center of astrophysics—especially theoretical astrophysics—for the last half of the 20th century, until Spitzer and Schwarzschild both died within a few weeks of each other in the spring of 1997.

A few words on how Spitzer planned and carried out his return to Princeton give insight into both his character and the times in which he lived. The year is 1946. Lyman is aged 32 and an associate professor at Yale. With great aplomb, he writes to the then leading light of astrophysics, Professor Harlow Shapley of Harvard College Observatory, who it appears had been commissioned by President Howard W. Dodds of Princeton to find a successor to the retiring

Princeton professor Henry Norris Russell. He begins his covering letter on a positive note.

For many reasons, I believe that the chairmanship at Princeton offers very great opportunities of the sort which interest me, and I would definitely accept an offer from Princeton University if it were along the lines which I visualize, and which I describe below…

The most important aspect of the Princeton opening, from my point of view, is the general policy of the University administration toward the Astronomy Department.

He includes in the letter rather precise details of the form of funding required from Princeton, the nature and title of positions required, and ends with characteristic formal but firm courtesy.

My own respect for the astronomy at Princeton in general and for Professor Russell in particular is so profound that it would be a great personal pleasure for me to come to Princeton under almost any conditions. The very strong support which astrophysics enjoys at Yale, however, would make it very difficult for me to leave New Haven, with it[s] opportunities for effective research and growth, unless the corresponding opportunities at Princeton are at least as great.

If the authorities at Princeton would like to discuss these proposals with me, I shall be very glad to visit Princeton in the near future. Naturally I should appreciate receiving your reaction and that of the Princeton administration to these ideas.

His plans for Princeton, described in an attachment to his letter to Shapley, asked for the resources to build a theoretical astronomy program in Princeton worthy of the opportunities of the age and the traditions of that institution. Excerpts from this document follow:

Princeton University is justly known as one of the world's leading centers of theoretical astronomy. This reputation has been built up over a considerable period of years, and should be preserved. The plan presented here is devised to continue this historical tradition in the field of theoretical astrophysics, and at the same time to preserve a balanced department by maintaining research in an observational field that is an integral part of the Princeton tradition—precise photometry of variable stars. In the first section below the scientific aspects of the plan are discussed, while the cost estimates are presented in the second section. It should be emphasized that in detail this plan is to be regarded as somewhat flexible, since its execution would naturally depend on the availability of qualified personnel as well as on the facilities at Princeton.

1. Scientific Program

It is proposed that the primary effort in astronomy at Princeton continue in the field of theoretical astrophysics, with three men of professorial rank in this field—the Director, Professor Stewart, and an additional man. Dr. Martin Schwarzschild would be an excellent choice for this third position, and there is reason to believe he might accept an offer of this type. If he were not available, and if no one of similar caliber could be found, a temporary Visiting Professor could be brought in, possibly a new man every year. On Professor Stewart's retirement, in some 15 years, it is assumed that his place would be taken by another theoretical astrophysicist with wide abilities and broad training.

To keep theory in touch with current observational problems, it is planned that in the near future the two new members of the permanent staff would each spend one academic term out of every four in a major observational center such as the Mount Wilson Observatory. It is understood that staff members would continue to receive their usual stipend from Princeton while carrying out research at other observatories in this manner. Such an arrangement would provide, at very moderate expense to Princeton, the observational facilities afforded by the world's largest telescopes. It is believed that the material obtained in these trips could also be used by Princeton graduate students, in keeping with the Princeton tradition.

Such a staff as outlined would serve as a center or focus of an active research group. A number of graduate students should be attracted each year by such a stimulating department. If a governmental Science Foundation is set up, and if such a Foundation decides to support theoretical astrophysics on a substantial scale, the astronomy Department at Princeton would make an ideal focus for such support. To cross-fertilize the different fields of astronomy, and to keep theorists and observationalists in touch with each other, it would be desirable to bring scientists from other institutions to Princeton from time to time for joint consideration of the major problems under study by astrophysicists. Thus the establishment of a considerable number of Visiting Professorships, financed by some governmental research unit, seems a definite possibility.

Well, as they say, the rest is history. All happened, as so often in Spitzer's life, exactly as he had planned. Princeton University Observatory became the world's leading institution in theoretical astrophysics almost instantly, with the addition of Spitzer and Schwarzschild, their students and associates. When formally offered the directorship at Princeton, Spitzer made his acceptance conditional upon the appointment of Schwarzschild as professor. At this time in history, when the Jewish faculty at Princeton was rare to nonexistent, this was taking a rather forceful stand. Building upon the foundation established by Henry Norris Russell, Spitzer and Schwarzschild together created a department with an enduring cordial atmosphere of mutual support and encouragement for astrophysical research at the highest level. The tradition of rigorous and creative scientific scholarship made Princeton a preeminent center of astrophysical research in the world. Many of his students went on to distinguished careers in astronomy.

Before turning to Spitzer's scientific work, let me say a word about his character and personality. While a paragon of personal integrity, he was also able to ascertain where his own advantage lay in every circumstance. So, in explaining why he had not early on accepted a junior position at Princeton, he later noted dryly, "It appeared that my chances of being offered Russell's position, if it became available, might well be greater if I were back at Yale than if I were already at Princeton." He loved pranks and sumptuous desserts. His pranks occasionally landed him in trouble, and he was essentially arrested by the Princeton University security police when he was found climbing up the side of the tower of the graduate college with a rope and possibly even pitons. It was with some difficulty that the limbs of the law were persuaded that he was a distinguished scientist, a chair of an academic department, and had in fact violated no written law! Other spoofs were more abstruse. He contributed a brief paper filled with plausible but insane mathematics under the pseudonym H. Pétard (actually the paper was written with J. Tukey) to the *American Mathematical Monthly* in 1938 entitled "A Contribution to the Mathematical Theory of Big Game Hunting."

Lyman also had rather strong and very highly principled but quite private political views. During the 1972 presidential campaign between Richard Nixon and George McGovern, he made a formal date with me to discuss "some nonastronomical matters." When I appeared in his office, he asked me directly, "What is your opinion of the character of Richard Milhous Nixon?" Delirious with the opportunity to vent my own rather intemperate, negative views, I carried on with vigor at length. Then, as I paused for a breath at one point, he stood up (signifying that the meeting was at an end), offered me his hand, and said, "Jerry, thank you so much. I greatly value learning your views on the many topics that you follow more closely than do I." Years later I was told by an individual I thought to be reliable that Lyman was on one of Nixon's extended "enemies lists," presumably due to his large financial contribution to Nixon's opponent. I was never able to confirm this, but when I asked Lyman about it directly many years after the event, his equivocal reply was, "I did not think much of McGovern, but I firmly concurred with your view that Nixon did not have a character suitable to be the President of the United States of America."

What kind of a scientist was he? Lyman Spitzer chose to tackle big, challenging problems. He wrote classic theoretical papers that helped shape at least three different fields of science: interstellar matter, the dynamics of star clusters, and the physics of plasmas. In addition, he proposed one of the leading methods for magnetically confining thermonuclear fusion and led a pioneering effort to do so at Princeton. And, finally, by both example and inspired leadership, he was a prophet and among the most influential proponents of the U.S. effort in space astronomy. Selected writings of Lyman Spitzer Jr., *Dreams, Stars, and Electrons,* published by Princeton University Press in 1997, provides a useful introduction to Spitzer's work in all of these areas.

The sheer volume of work is staggering, with four monographs and more than 100 articles in refereed scientific journals (and double that number if one were to include other widely cited and influential contributions) in over half a century of active research. Spitzer's trademark was the incisive physical insight, coupled with the ability to formulate and accurately solve appropriate model problems. The impact of his work is strengthened by a crisp and lucid style of exposition. He invariably discovered at the outset of an investigation which were the important physical effects to be modeled carefully and which processes could be ignored in the initial assay. This is a skill that cannot easily be taught, but the readers of Spitzer's papers will come away with a vision of how a remarkable scientific mind works.

In the late 1930s Spitzer was struck by the fact that elliptical galaxies contained old stars but no large amounts of interstellar gas, whereas spiral galaxies that contained substantial amounts of gas also had young stars. He concluded that stars must be forming even today from clouds of gas and dust. Today this is obvious, but at that time the realization that star formation is an ongoing process was quite new to astrophysics. It took decades for the implications to sink in. Spitzer began a theoretical study of the physics of interstellar matter that lasted almost six decades. He worked on the theory of the heating and cooling of interstellar gases, stressing the presence and importance of interstellar magnetic fields, the likelihood of pressure equilibrium among various components, and the significant role played by interstellar dust grains. His investigations, which established the field of interstellar matter as a rich discipline, culminated in the publication of his classic book *Diffuse Matter in Space* in 1968, followed by *Physical Processes in the Interstellar Medium* in 1978. When I arrived as a wet-behind-the-ears, newly minted research associate and lecturer in 1965 after a year of "finishing school"—my postdoctoral year in Cambridge, England, paralleled that of Spitzer 29 years earlier—my first task was to provide a close reading of the manuscript for *Diffuse Matter in Space.* It was dense going for someone who, though well trained (by S. Chandrasekhar), had neither formal nor informal exposure to the subject matter, and I checked and rechecked every equation, reading with attention every line. I seriously doubt I added much, if anything, to the work, but the effort, the contact, and mentoring by Lyman as I taught the interstellar medium graduate course at Princeton certainly contributed crucially to my own most cited publication "A Theory of the Interstellar Medium—Three Components Regulated by Supernova Explosions in an Inhomogeneous Substrate," written jointly with C. F. McKee in 1977 (*Astrophys. J.* 218:148-169).

Spitzer, following H. Alfvén, helped to establish the physical and mathematical foundations of plasma physics in the 1950s. Spitzer recognized early the importance of determining the thermal, electrical (the "Spitzer conductivity"), and mechanical transport coefficients in a fully ionized gas, and he made the initial calculations of thermal and electrical conductivities and diffusion coefficients for plasmas. His pioneering studies in basic plasma physics culminated in the volume *Physics of Fully Ionized Gases* (1956), which became a classic, oft cited text, central to the education of successive generations of plasma physicists. He also carried out the first computations of the toroidal confinement of a plasma.

Following up on his theoretical work in plasma physics, Spitzer proposed to the U.S. Atomic Energy Commission (in 1951) a project to try to contain and harness the nuclear burning of hydrogen at temperatures exceeding those found on the sun, terming the machine a "Stellarator," which would be "designed to obtain power from the thermonuclear reactions between deuterium and either deuterium or tritium." First approved as Project Matterhorn in 1953, the Princeton Plasma Physics Laboratory at the James Forrestal Campus became the leading laboratory in this field. After shepherding its creation, Spitzer led the laboratory until 1967. Now, in 2006, over half a century after the founding of Project Matterhorn, the laboratory is returning to the Stellarator concept, hoping to demonstrate the power of hydrogen fusion. This was the design first proposed by Spitzer in the paper entitled "The Stellarator Concept," published by *Physics of Fluids* in 1958. Big science was still a hands-on activity in this era and Spitzer notes:

> The Atomic Energy Commission (AEC) supported the idea, after we had persuaded Jim Van Allen at Iowa to head this work for a few years. Van wisely suggested that we start with a simple, modest device. The resultant "Table-top stellarator," our Model A, was indeed primitive. Martin Schwarzschild and I spent several weekends sitting on the floor of our rabbit hutch, winding flat copper wire around 2-inch diameter glass tubes.

It is an extraordinarily apt measure of Spitzer's prescience that Princeton Plasma Physics Laboratory is now, one-half century after Lyman proposed it, building, after an international technical review, what may be the most promising design yet for taming the physical process that makes the stars shine; the National Compact Stellarator Experiment (NCSX) is scheduled to begin operation in 2009.

In stellar dynamics Spitzer clarified the process of "relaxation" introduced by S. Chandrasekhar and showed how this leads a stellar system to approach a singular state, as the effective conduction of heat outward in the star cluster (caused by gravitational interactions between pairs of stars) forces the inner parts to contract more and more rapidly. He discussed how the relaxation process in real star clusters is accelerated by the existence of a spectrum of stellar masses, but retarded by the presence of binary stars. His many contributions to the field were summarized in 1987 in the book *Dynamical Evolution of Globular Clusters.*

Spitzer's seminal contributions to space astronomy are legendary and were recognized in 2003 when the large infrared space observatory launched earlier that year was named the Lyman Spitzer Telescope. One important reason for this recognition was that this telescope was optimized to see the infrared radiation emitted by dust from the dense gaseous regions within which all stars seem to form, and Spitzer had carried out pioneering studies of the physics of interstellar dust. In 1941 he discussed the important dynamical effects of radiation pressure acting on interstellar grains. In 1948 he investigated the effects of dust grains on the temperature of interstellar gas, recognizing the important heating effect of photoelectrons ejected from interstellar grains. To estimate this heating rate Spitzer carried out pioneering work on the charging of interstellar grains, a problem he returned to in 1950, noting the different levels of grain charging to be expected in different interstellar regions. In 1949 the phenomenon of starlight polarization was discovered and immediately identified as being due to the polarizing effect of aligned interstellar dust grains. It was not clear what physical process could produce the observed alignment, and to this date this question has not been fully answered. Spitzer was attracted to this problem, and over the years made a number of important contributions.

In 1946 he proposed, in a report under Project RAND titled "Astronomical Advantages of an Extra-Terrestrial Observatory," the development of large space telescopes. In the abstract he points out, quite amazingly for what appears to be the first time, "the results that might be expected from astronomical measurements made with a satellite vehicle… While a more exhaustive analysis would alter some of the details of the present study, it would probably not change the chief conclusion—that such a scientific tool, if practically feasible, could revolutionize astronomical techniques and open up completely new vistas of astronomical research." He then goes on to outline the advantages to be gained due to greater angular resolution (overcoming astronomical "seeing" problems), to the increased wavelength coverage available, and to the stability of a low-gravity environment. He continued to lobby for an astronomical space program, using after 1966 the Space Science Board of the National Research Council as a platform for his efforts.

All of the benefits foretold have been realized by present satellite experiments, with Spitzer having been a major contributor to their realization. Under his direction a group of Princeton scientists developed the extremely successful *Copernicus* (32-inch) ultraviolet satellite. Launched in 1972, it made a number of significant astronomical discoveries, including among them an accurate value for the cosmologically important ratio of deuterium to hydrogen in interstellar space. But this satellite barely escaped being a total failure. In Florida just before launch when much of the team was partying, Lyman, studying technical specifications, discovered a potential defect in the engineering that might have caused the instrument to lock in place and be undeployable. He computed where to set the focus and telephoned his results to the launch site. As it eventuated, his diligence was amply rewarded, because the drive motor did fail and his timely action saved the mission.

Lyman really enjoyed getting into the nitty-gritty engineering details on which success or failure of such missions can rest. Discoveries made by the *Copernicus* satellite led to fundamental changes in our understanding of the interstellar medium. The current, very productive Hubble Space Telescope, which was approved in 1977 and launched in 1990, is now returning incomparable pictures of the cosmos, and was in a quite literal sense Spitzer's brainchild. He played major roles in shepherding it through many difficult stages of its existence from the earliest planning to its recent refurbishment. At certain critical points this required heavy old-fashioned lobbying of Congress with John Bahcall (from the Institute for Advanced Study). His evident enjoyment and success in these ventures surprised those who (erroneously) considered him to be shy. Spitzer continued to sit as an elder statesman on the Space Telescope Institute Council, providing wise guidance for this extraordinarily important scientific venture until his death in 1997.

In addition to his purely scientific skills, Spitzer's vigorous personality, sound judgment, and basic human decency propelled him to positions of leadership at a variety of levels. At Princeton, where he was chair of the Department of Astrophysical Sciences and director of the observatory for a third of a century (1947-1979), he built one of the world's leading institutions for astronomical education and research, with an almost unique atmosphere for research. The congenial and supportive (and rather formal) environment Spitzer created in collaboration with his brilliant colleague Martin Schwarzschild, where the generous interest of each scientist in the other's research led to increased productivity and originality, as well as the cross-fertilization exemplified best by Spitzer's own work, was widely admired but not easily imitated.

Spitzer took his teaching very seriously. For decades he gave a course on the physics of the interstellar medium, and the accompanying monograph, *Diffuse Matter in Space*, (1968) established a new scientific field and educated a generation of students who, as they settled into other institutions, propagated these teachings. Not all worked in this area, and a brief list of the Ph.D. students supervised in whole or in part by Spitzer and went on to distinguished careers in astrophysics would certainly include B. Elmegreen, G. Field, J. Gaustad, J. R. Gott, C. Heiles, D. Morton, B. Oke, R. Sanders, T. X. Thuan, L. Searle, and R. Weyman.

As a national scientific administrator, he served as director of the wartime Sonar Analysis Group (1944-1946), president of the American Astronomical Society (1958-1960), and chair of the Space Telescope Institute Council (1981-1990), and held other major national leadership positions on numerous committees, commissions, and the like that guided the scientific life of the nation. Spitzer's service to his country was recognized with medals for scientific achievement and national service from NASA in 1972, 1976, and 1991 and the U.S. National Medal of Science in 1980. His scientific work received worldwide recognition, and he was the recipient of many honors, including membership in the National Academy of Sciences in 1952, the Henry Norris Russell Prize of the American Astronomical Society in 1953, the Henry Draper medal of the National Academy of Sciences in 1974, the James Clerk Maxwell Prize of the American Physical Society in 1975, the Crafoord Prize of the Royal Swedish Academy of Sciences in 1985, and the James Madison Medal of Princeton University in 1989.

He was an enthusiastic music lover, and an active mountain climber (making the first ascent of the spectacular Mt.

Thor on Canada's Baffin Island). And, even in retirement, he barely slowed his active outdoors life, continuing to indulge his passion for climbing and endowing the Lyman Spitzer Climbing Grants of the American Alpine Club to support cutting-edge climbing expeditions. Spitzer formally retired in 1982 but did not slow his active involvement in forefront research, involving both theoretical work and, following the launch of Hubble Space Telescope, observational studies using the high-resolution spectrograph to study interstellar absorption lines. On March 31, 1997, Spitzer spent the day in Peyton Hall, working on a scientific manuscript, and happily discussing recent developments with his colleagues. At home that evening after a full day of work, he suddenly collapsed and died, concluding an extraordinary and exemplary life.

THE AUTHOR IS INDEBTED to Professor B. T. Draine for providing a summary of Spitzer's work on dust grain physics.

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