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Foggy Vision

The sky was dark, the air clear. It was an excellent night for astronomical photography.

On March 7, 1945, Enrique Gaviola of the Cordoba Observatory of Cordoba, Argentina, carefully positioned the observatory's 61-inch telescope for an evening of research. Painstakingly, methodically, Gaviola aimed the telescope at one of the more spectacular spots in the southern sky, the Keyhole Nebula in the constellation Carina.

First observed by John Herschel in the mid-1830s while in South Africa doing a survey of the southern sky, it had been given its name by Herschel because of its distinctive keyhole-shaped dark patch. What made this particular place in the sky even more intriguing was that on December 16, 1837, Herschel had been surprised to see a new star shining brightly there. "[The star] had come on suddenly," he wrote that night in a letter to Thomas Maclear, the astronomer at the Royal Observatory at Cape Town.

At first Herschel thought the star might be what was then called a bright nova, similar to those discovered in 1572 and 1604, and now dubbed supernovae. After some careful measurement, however, he realized that the gleaming, unexpected spark above him was not a new star suddenly bursting into visibility, but the star Eta Carinae, shining three times brighter than he had ever seen it before, and approaching 1st magnitude.

For several hours into the wee hours of the morning Herschel stared at this inexplicable object. For years it had remained unchanged to him, shimmering at about 2nd magnitude just off the edge of the Keyhole itself. In fact, only a week earlier he had noted the star's annual arrival in the December evening sky, and had commented to his chief assistant that "We must soon begin [studying] him again."

Before Herschel could "begin," however, the star had suddenly become one of the brightest in the sky. Unable to contain his excitement, he called his wife, his assistant, and his personal butler all out of bed to have them look and confirm what he saw.

As he wrote that night to Maclear, "How big *will* it grow?"

In the thirty years that followed Eta Carinae faded in fits and starts from 1st to 7th magnitude, while the darker parts of the much larger Keyhole Nebula slowly brightened so that it no longer stood out so distinctly.[1]

In the twentieth century astronomers returned to this star periodically, trying to figure out what had happened in 1837 as well as afterward. Though some thought the nebulosity surrounding the star was slowly growing, in 1932 astronomer Bart Bok of Harvard concluded decisively that this was an imaginary effect.[2] In fact, most observers in the early twentieth century assumed that the faint collection of bright hazy spots surrounding Eta Carinae were actually a handful of individual stars, embedded in a gas cloud.

Now, more than a hundred years after Herschel, Enrique Gaviola was back, taking another careful look at Eta Carinae. For several hours he took two sets of nine images, beginning each set with a one-second exposure and doubling the exposure duration each time until the exposure for his last picture was over four minutes long.

Once developed, these images from 1945 were considered by many the best ever taken of this strange star. They showed what Gaviola humorously dubbed the Homunculus, Latin for "little man," a kind of Pillsbury Doughboy "with its head pointing northwest, legs opposite and arms folded over a fat body."[3]

As good as Gaviola's photographs were, they were generally fuzzy and revealed little detail. The best that Gaviola's images could do was to show that the hazy bright spots surrounding Eta Carinae were probably not multiple stars but several gas shells and clouds enveloping the star and illuminated by it. Moreover, he was able to extrapolate backward and conclude that the nebula was formed "by clouds ejected by the star around 1843," about the time of a second outburst following Herschel's initial 1837 discovery.

Why the expansion happened, how it was unfolding in detail, and where it was going to end up, however, was utterly impossible for Gaviola to deduce from his nebulous images. Gaviola's photographs, as

Fig. 1.1. A sequence of four images of Eta Carinae, taken by Enrique Gaviola, March 7, 1945. The exposure times, from left to right, are 256, 128, 64, and 32 seconds. In all the Eta Carinae images, north is up and east is to the left. (Photo by Enrique Gaviola, provided courtesy of Arnout van Genderen)

groundbreaking as they were, were typical of all astronomical images since the invention of the camera. The atmosphere that we breathe and that makes life possible also acts as an annoying translucent curtain, blurring our vision of the sky. Just as a prism will bend the light that passes through it, so does the atmosphere. The atmosphere, however, is in constant flux, causing the path of that light to shift and jiggle. When we look up at a star, this shifting makes it appear to twinkle. On a photographic plate this twinkling in turn causes the accumulated light to spread out so that a truly sharp image is just not possible.

The result: before the advent of space flight astronomers, both professional and amateur, were left thwarted and unsure about what they saw. For someone like myself, who has poor vision and requires glasses, this situation is self-evident. Though the metaphor is not technically correct, for me to understand the limited view of the heavens from the beneath the atmosphere, all I have to do it is to take off my glasses. Everything becomes fuzzy, unclear, and indistinct.

I, however, can buy eyeglasses. Until the late twentieth-century astronomers had no such option. Trapped on the Earth within its unsteady and hazy atmosphere, astronomers were condemned to look at the heavens as though they had bad vision and were forbidden from using glasses.

The consequences of this hazy situation have been both frustrating and profound. Consider for example the efforts of Giovanni Schiaparelli and Percival Lovell to map the surface of Mars in the late nineteenth and early twentieth centuries. Beginning in 1877 Schiaparelli studied Mars nightly, using an 8.6-inch telescope at the Brera Observatory in Milan. After more than a decade of work he finally published his map, outlining a wide range of vague shapes and streaks on the Martian surface. Of greatest interest were what he called "*canali*" (which means "grooves" in Italian).

Though Schiaparelli was convinced the *canali* were real, he found that their

> . . . aspect is very variable. . . . Their appearance and their degree of visibility vary greatly, for all of them, from one opposition* to another, and even from one week to another . . . . often one or more become indistinct, or even wholly invisible, whilst others in their vicinity increase to the point of becoming conspicuous even in telescopes of moderate power.[4]

Percival Lowell followed Schiaparelli with decades of more work, studying Mars's surface and making endless sketches of what he thought he saw there.

From Lowell's perspective, the complex series of straight lines that crisscrossed Mars strongly suggested what could only be artificial constructs, which he labeled more bluntly as canals. As he wrote in 1895, "There is an apparent dearth of water upon the planet's surface, and therefore, if beings of sufficient intelligence inhabited it, they would have to resort to irrigation to support life."[5] To Lowell, the canals appeared to be built by the inhabitants of the red planet as a vast irrigation system to stave off the consequences of an increasingly arid planet.

For the next seventy years the human race debated the possibility of life on Mars. Lowell's thoughts inspired such classic works of fiction as H. G. Wells's *War of the Worlds* as well as a plethora of science fiction books and movies.

Then, in the mid-1960s the United States sent a series of unmanned probes to Mars to take the first close-up images—and burst Lowell's bubble. Mars has no canals, no intelligent life. The canals were an optical illusion created by the Earth's varying atmosphere.

The atmosphere causes similar problems across the entire field of astronomical research. Worse, not only does it distort optical light, it en-

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* Opposition is the moment each year when the Earth is exactly between the Sun and Mars, and therefore best positioned for viewing.

tirely blocks large portions of the rest of the electromagnetic spectrum. Except for radio wavelengths and a few select infrared wavelengths, the majority of the infrared and all of the ultraviolet, x-ray, and gamma ray regions of the spectrum are inaccessible to astronomers working from the surface of the Earth. This fact is especially crippling because the bulk of astronomical research is done through spectroscopy, and much of the most interesting and informative spectroscopy needs to be done in these unavailable wavelengths.

For example, by observing the spectrum of light coming from a star, astronomers can gather information about that star's chemical makeup. Each element when heated emits light at a specific wavelength. If you see a spike of light at that specific wavelength you know that element is present in a star's atmosphere. Similarly, if there is a dip of light at that wavelength you know that that element is standing somewhere between you and the star, either in the star's surrounding nebula or in some intervening gas in interstellar space, absorbing that light. Unfortunately, the spectral signature of a large percentage of the most interesting elements occurs at wavelengths outside visible light in parts of the electromagnetic spectrum that are blocked by the atmosphere.

In the visual wavelengths, meanwhile, the atmosphere's blurring action makes the interpretation of the astronomical data more challenging. Our brains are tightly wired to our eyesight. Very roughly speaking, if we cannot see a clear image of something, it is difficult for us to fully grasp what is going on, no matter how much other information is available. Conversely, if we have a good image to look at, we can more easily interpret all the other data and understand how they fit into that visual image.

Consider for example what astronomers call planetary nebulae. These objects were given that name because at first glance they seemed to resemble planets, but by the 1800s scientists had realized that the nebulae were not planets at all but distant stars surrounded by large and beautiful cloud structures.

By the early 1960s astronomers were reasonably sure they understood their origin. When a star like the Sun has used up most of its hydrogen fuel and begins burning helium, it becomes unstable, starts to pulse, and ejects mass in a series of expanding shells. After some ten to fifty thousand years these shells form a planetary nebula, which surrounds a slowly dying and cooling white dwarf star.

This theory, however, did little to explain the complex but hard-to-see structure of the encircling clouds visible in pre-Hubble astronomical photographs. In most cases the nebula looked like one or several rings. For example, in long photographic exposures the Ring Nebula in the constellation Lyra resembled a bluish-green oval with horizontal wreathlike veils cutting across its central regions. Similarly, the Helical Nebula in Aquarius looked like two overlapping rings, though the best photographs also showed strange spokelike features pointing inward toward the central star. Other planetary nebulae, such as the Dumbbell Nebula in the constellation Vulpecula, looked as if we were viewing the ring edge-on so that it resembled a barrel on its side.

Because so many of the nebulae had this ringlike morphology, it was assumed that they were really shells or bubbles, with only the outer edges visible because our line of sight was looking through the most material. Such an assumption conformed nicely to the idea that the shells were the debris from the star's earlier helium-burning stage, when it repeatedly ejected large amounts of mass.

Other planetary nebulae, however, did not conform to this theory. Some appeared irregular, patchy disks with no discernible pattern. Others had weird shapes, making any interpretations difficult if not impossible. For example, the Owl Nebula in Ursa Major had an outer ring, but instead of an open interior its central regions looked more like an hourglass, two conelike shapes pointing inward toward the central star. And the Saturn Nebula in Aquarius was even more baffling: it had two rings, each inclined at a different angle to our view. Especially baffling were the two spikes of material at opposite ends of the nebula pointing away from the central star. For these inexplicably shaped planetary nebulae, several theories were proposed to explain their formation, including the possibility that the spikes were jets emanating from the poles, or some form of slow expansion influenced by either magnetic fields or unseen binary companions.

Because the images were so fuzzy and indistinct, however, it was difficult for scientists to reach a consensus on any specific theory. And though spectroscopy provided a great deal of information about the motion within each nebula's surrounding gas cloud, it was often difficult to untangle this spectral velocity data into a coherent picture without a corresponding sharp visual image. Thus, few astronomers made a serious effort to explain the formation of these nebula shapes because the data were so imprecise.

The problem was the same for galactic evolutionary theories. It was impossible with ground-based telescopes to see any galaxies from the early universe, and thus get a longer view of the evolution of galaxies across time. These distant objects were simply too faint to be picked out from the blurring effects of the atmosphere. Similarly, there were a number of very strange-looking distant galaxies, such as the Antennae Galaxy in the constellation Covus, with its two long trailing tails and two warped central blobs, whose shapes ground-based telescopes could not image sharply. Though astronomers were able to put together a number of theories about galaxy mergers or collisions to explain these unusual structures, any one of these ideas could be right. Worse, until better and more precise data were available, including information from the wavelengths blocked by the atmosphere, it was also quite possible that none were correct.[6]

In various areas of astronomy this problem repeated itself. Astronomers could put together reasonable theories to explain their data, but without clear optical images it was difficult to confirm which theories were the most accurate.

For the general public, the situation was worse. Dependent as we humans are on our eyesight, the atmosphere essentially left the human race blind to the heavens. We were like a nearsighted man before the invention of eyeglasses. We could squint and strain and maybe make a guess at what we were looking at, but to actually perceive the reality of the universe in all its glory was nigh on impossible.

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Even as Gaviola was slowly developing his photographs and preparing his paper for publication—crippled as he was by being at the bottom of a 100-mile-thick fog filter—another astronomer almost half a world away was about to take the first step in what would become an epic, half-century-long odyssey to solve this centuries-long dilemma. This man was about to propose that the United States build the first optical telescope in space.

World War II had just ended. At the time Lyman Spitzer, Jr., was a thirty-one-year-old astronomer doing war work as head of a research organization called the Sonar Analysis Group. Though most of his group worked in the Empire State Building in New York, Spitzer's headquarters and base of operations was in Washington, DC. As Spitzer explained in a 1978 interview, "My work involved talking with people who were doing [sonar] research and telling them what they were doing wrong and what they ought to be doing."[7]

Before the war Spitzer had been a young post-graduate astronomer working at Yale University. Now that the war had ended he wanted to get back to astronomy work.

In the fall of 1945, however, Spitzer was still working in Washington, DC. Among the many scientists he ran into in DC who were part of the war effort was a geophysicist named David Griggs. During the war Griggs had been part of a group of scientific advisors working under Dr. Edward Bowles, who had been named special assistant to Secretary of War Henry Stimson. Under Bowles's leadership, Griggs and his cohorts had been key on-site technical advisors during the D-Day invasion, the campaign in France, and later during the Battle of the Bulge. As noted by historian James Baxter, "They evacuated equipment at the last moment, they served as pinch-hit operators of gear in crucial spots, often under fire."

Now that the war was over, the military research group that Griggs was involved with was undergoing a reorganization. He explained to Spitzer how the Air Force was forming a new secret group at the Douglas Aircraft factory out in Santa Monica, California, called the RAND Project (for Research ANd Development). Though not yet finalized, RAND's first report for the Air Force was to be on the benefits of rockets and orbiting satellites and titled "Preliminary Design of an Experimental World-Circling Spaceship." Griggs, active in the development of this project, asked Spitzer if such a spaceship could have uses for astronomy.[8]

Spitzer was immediately intrigued. To him, the idea of putting a telescope in space was both scientifically and emotionally appealing.

Over the next few months, as he wrapped up his war work and returned to teaching astronomy at Yale University in New Haven, he kept in touch with Griggs and others in Santa Monica, letting them know that he was interested in providing his input should the project get started. When on March 2, 1946, the Air Force and the Douglas

Fig. 1.2. Lyman Spitzer with his children, Sarah, 1, Dionis, 5, and Nicholas, 8, on Nicholas's birthday in Princeton, 1950. (Photo courtesy of Sarah Lutie Spitzer Saul)

Aircraft Company signed a $10 million contract to form RAND, Spitzer quickly made arrangements to spend a week at the Project RAND headquarters in the Douglas Aircraft factory, where he wrote a paper for the project called "Astronomical Advantages of an Extra-Terrestrial Observatory," describing in detail the scientific advantages of building a telescope in space.

Spitzer was by far not the first to suggest the advantages of placing a telescope above the Earth's atmosphere. Hermann Oberth of Germany was the first to describe the advantages of building a telescope in space in his 1923 groundbreaking book, *Die Rakete zu den Planetenraumen* ("By Rocket into Planetary Space"), originally written as his doctoral dissertation but rejected by his school advisors and then published privately. In 1933, Henry Norris Russell, the director of the Princeton University Observatory and the man under whom Spitzer had gotten his degree, bemoaned his inability to do ultraviolet spectroscopy because of the Earth's atmosphere, and dreamed of an astronomer's heaven where he was "permitted to go, when he died, instruments and all, [to] set up an observatory on the Moon." Then in 1940, writing for the science fiction magazine *Astounding Science Fiction*, astronomer Richard Richardson proposed his own concept for building of a 300-inch lunar telescope.[9]

What made Lyman Spitzer's 1946 paper different, however, was that it was concrete, realistic, and based on technology that was either available at the time or expected to be developed in the coming decade. He was not speculating or exercising a mere flight of fancy. He was applying the increasingly available new technology of rockets—demonstrated by the V2 rocket during the war—and suggesting it be used to place a telescope in space.

Nonetheless, Spitzer's proposal was hardly conservative. Though he described the possibilities of research using an orbiting 10-inch telescope, he quickly went on to propose the construction of something that was far more ambitious, an orbiting reflecting telescope with a mirror 200 to 600 inches in diameter.

You have to understand the context of this proposal to realize how audacious it was. In 1946 the 200-inch Hale Telescope on Palomar Mountain in California, soon to become the largest ground-based telescope in the world, was not yet finished. It had taken almost three decades to build, and it would not even be dedicated until a year later. Moreover, when finished it would weigh a million pounds and be almost seventy feet tall. In addition, in 1946 when Spitzer wrote his report, the first orbiting satellite was still more than a decade away, and that spacecraft—Sputnik—would weigh a mere 185 pounds.

Yet here was Lyman Spitzer proposing that the United States not only consider building a telescope as much as three times bigger than the Hale

Telescope *but also put it in orbit around the Earth.* As Spitzer noted in his report, such a project would not only provide humanity with its first clear view of the heavens, it would more importantly "uncover new phenomena not yet imagined, and perhaps . . . modify profoundly our basic concepts of space and time."[10]

At first glance Lyman Spitzer did not impress people as being such a wild-eyed dreamer. Tall, thin, and gangly, his soft-spoken and gentle manner gave one the impression that he was happier buried among a pile of books than pushing the risky unknown. Moreover, he had spent almost his entire life in the academic world.

Spitzer came from traditional New England stock, his ancestors first arriving in America in the mid-1700s. His father had gone to school at Andover, then Yale, then became a successful and wealthy businessman, first as a municipal bond salesman and then as the owner of a paper box factory in Toledo, Ohio.

With that money A. Lyman Spitzer, Sr., was able to travel, taking his family on trips to France, Switzerland, England, California. In 1925–26, when Spitzer junior was eleven, the family lived in Paris for six months. Later they spent four months in Rome. "We got around a bit," Spitzer remembered in 1977.[11]

Following in his father's footsteps, Spitzer started his studies at Andover and continued at Yale. After this, however, Spitzer didn't go into business like his father, but continued in academia, going to Cambridge University in England on a scholarship, then Princeton, where he earned his PhD, then Harvard as a fellow, and then back to Yale as a teacher. By the time he was thirty-three he was the chairman of the Princeton astrophysical sciences department, taking over for Henry Norris Russell, his academic mentor.

As privileged as Spitzer's upbringing might seem, he did not grow up spoiled. For Spitzer, astronomy and intellectual studies were a natural passion, and he pursued them relentlessly. Moreover, he had an ardent fascination with the idea of doing things that no one had ever done before. While in college he became fascinated with science fiction, and dreamed up his own transcontinental transportation system using electromagnetic suspension. "Small cars would travel in tubes between cities, and end up various places within the city, and might even, in tall buildings, go up and stop at one of the high floors," he explained in 1977.

Yet, even as he fantasized about building this vast transportation network, Spitzer also recognized, with an easygoing and witty self-depreciation that made people like him, how wild-eyed the fantasy was. “I told my father about this, and he began to think I was going off the deep end.”[12]

Through it all, Spitzer always seemed to keep a placid and good-natured view of the world. “I’ve never been a fighter, by profession,” he mused in 1977. “I go out of my way to keep things on a friendly basis . . . . You can have controversy without being unfriendly.”[13]

Despite Spitzer’s upscale and bookish background, he was a remarkably fearless and athletic man. For example, on July 28, 1945, he was working in an office on the 64th floor of the Empire State Building—he liked to joke how he hunted enemy submarines from these heights—when an Army B-25 bomber got lost in the fog and crashed into the north side of the building, plowing into the 78th and 79th floors.

Because the windows had been closed Spitzer only heard the zoom of the plane, which for some strange reason got cut off suddenly. Then, even more puzzling, he could see debris falling past his windows. With almost childlike curiosity, Spitzer walked over to the windows and started to open one, intent on peering out and up to see what had happened.

Another scientist, Peter Bergmann, had to actually hold him back, convincing him that this was not a good idea. “He was, of course, perfectly right,” Spitzer admitted cheerfully in 1978.[14]

His athletic skills became more evident after the war, when his love of the outdoors got him interested in the hobby of mountain climbing. At first he and his wife Doreen would take hiking trips to Europe and the Alps, exploring the mountainous regions while Spitzer looked longingly at their peaks. Then, in 1955 they arranged a guided trip to the Alps. After climbing a series of increasingly challenging mountains they capped their adventure with an ascent of the Matterhorn.

Once back in the States Spitzer began making regular caving and rock-climbing trips with his graduate student Don Morton. One time, in a letter to his family describing a recent very challenging mountain expedition, Spitzer wrote, “You may wonder what I find enjoyable in a mountaineering trip of this sort, and I confess I find myself asking this same question. Certainly most of the trip was not particularly comfortable. . . . Much of the time I was looking forward to the end of whatever I was doing. Yet I find a certain satisfaction in undertaking an adventure of this sort, and in pushing myself to the maximum effort."

"He loved it," Doreen Spitzer remembered. "It was a very great relief to him. . . . The challenge took his mind off of what he was doing." Spitzer's daughter Lutie Spitzer Saul explained her father's passion for mountains and rock climbing in another way. "For some people these heights are a substitute for spirituality."[15]

With such a bold personality, it is perhaps not surprising that Spitzer was willing in 1946 to propose building a telescope in orbit that was two or three times bigger than anything that had yet been built on Earth.

Spitzer's proposals were too farsighted, however, to gain acceptance, despite what seemed an enthusiastic response within government circles to this first RAND Corporation report. Throughout the late 1940s and most of the 1950s Spitzer found little interest in his space telescope idea. During those years before Sputnik, he spent most of his research time studying the empty regions of space between the stars and galaxies—trying to figure out the nature and makeup of these almost empty clouds of dust and gas from which new stars were thought to form—or building one of the first attempts to create a controlled fusion reactor, something he called the Stellarator.

This second classified project, dubbed Project Matterhorn in honor of his Matterhorn climb, was as farsighted as anything else Lyman Spitzer ever proposed. The idea was to build the first "magnetic bottle," designed to contain a gas made up of deuterium at 100 million degrees Kelvin long enough for a controlled nuclear fusion reaction to occur. As he wrote forty years later in a New York Times op-ed, "If we could replicate the process that powers the sun, we could create a source of virtually unlimited energy."[16]

The Stellarator was something right out of a 1950s science fiction movie. A tube two to four inches wide and ten to twenty feet long was twisted into an endless figure-eight shape and then charged with gigantic amounts of electrical energy. "Since the power required at the peak of the field is in the neighborhood of 50,000 kilowatts," Spitzer wrote in 1958, "the power bill has restricted operations to pulses lasting about 0.02 second."[17]

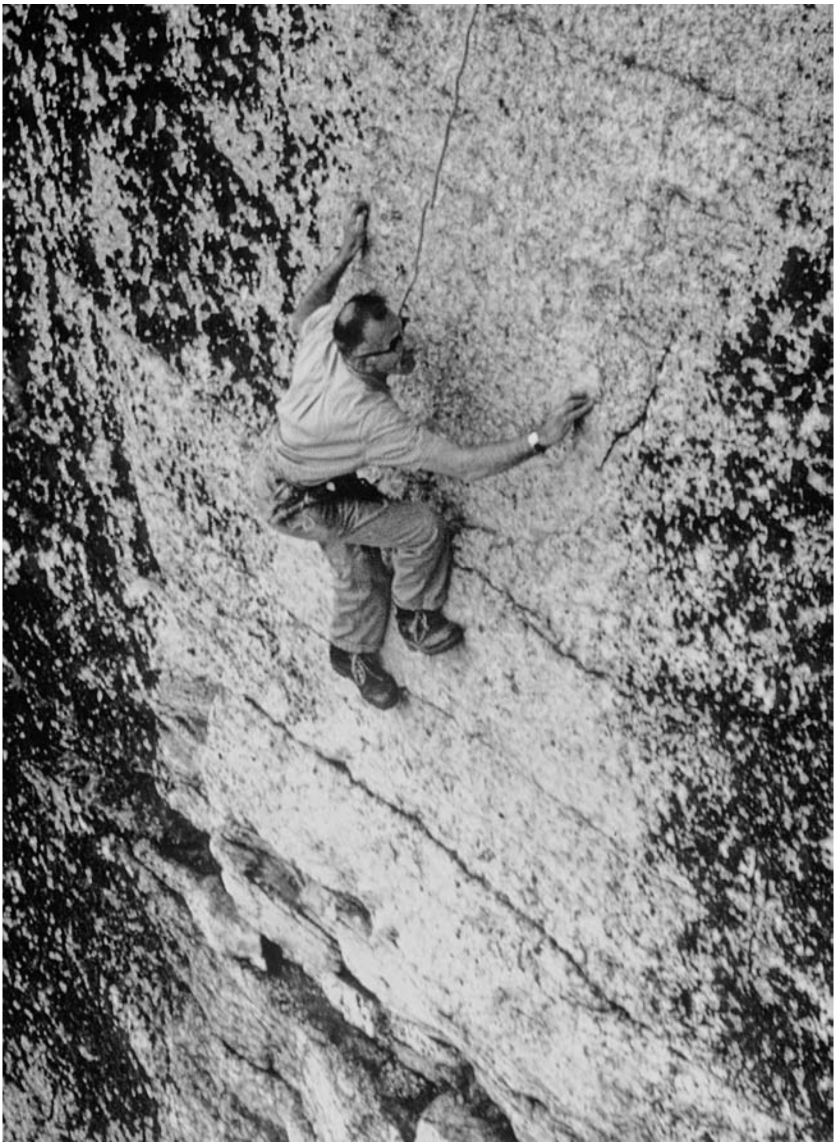

Fig. 1.3. Lyman Spitzer rock climbing in the Shawangunk Mountains, New York. (Photo by Don Morton)

In between building several Stellarators and his interstellar research, however, Spitzer never abandoned the idea of space exploration and its uses for astronomy. Periodically he would write carefully thought out papers for the journals of such organizations as the American Rocket Society or the British Interplanetary Society, describing the construction of a nuclear ion engine for traveling between planets or working out the orbital mechanics of a small satellite in a circular orbit around the Earth. Other times he would appear at conferences, advocating the idea of space exploration and its advantages.[18]

Though few people expressed strong hostility to his ideas, few showed much support, either. Scientists were especially skeptical. After one of his conference presentations a scientist came up to him and said, "Lyman, I admire your courage." Though he liked what Spitzer had said, he considered it somewhat far-fetched. "Most astronomers didn't take it seriously," Spitzer remembered in 1977. "They thought I was sort of . . . wild-eyed or wide-eyed, one or the other."[19]

Some astronomers were more harsh. In 1953, when astronomer Gerald Kuiper heard of Spitzer's proposals for space-based astronomy, he said, "I would regard the [funding] of this project hazardous and probably undesirable."[20]

Still, Spitzer persevered, often inspiring others into action and getting them to do things they would never have imagined doing. For example, one day in 1954, Spitzer was having lunch with two fellow scientists, Martin Schwarzschild and James Van Allen. Schwarzschild was a fellow professor in Princeton's astrophysics department, which Spitzer headed. Van Allen in turn was at the time one of the country's most respected space scientists, having used the V2 rocket extensively in the postwar era to do the first studies of the Earth's magnetosphere.

Van Allen was then on a temporary sabbatical from the University of Iowa to work with Spitzer on Project Matterhorn. Because the project was classified, Spitzer had been having trouble hiring good people. "It was difficult to add staff in those days because we couldn't say what we were doing, and our salary scale wasn't that high." Putting the very well known Van Allen in charge of the experimental group made it easier to convince others to join.[21]

Schwarzschild meanwhile had just returned from a sabbatical doing astronomical observations at the Mount Wilson Observatory. The son of the German physicist Karl Schwarzschild (who is most famous for taking Einstein's equations and using them to describe the environment around a black hole), Schwarzschild had fled Germany in 1936 because as a Jew he had been banned from working at any German university.

He came to the United States with fear and trepidation. "I did not want to spend my life [there]. . . . I had a simplified picture, to exaggerate a little, that the United States consisted of Indians, gangsters, and Mount Wilson."[22]

In the end he grew to love America more than many of its natives did. After Pearl Harbor, he immediately enlisted in the Army, going in as a buck private and ending up as an officer on special assignment with the Air Force on the front in Italy, where he analyzed the effectiveness of U.S. bombing. Though assigned a New York truck driver to get him around, his German accent more than a few times got him arrested as a German spy. As astronomer Virginia Trimble noted in her 1997 obituary of Schwarzschild:

> One can imagine the reaction of the officers *in situ* when asked by a stranger with a heavy German accent, "Please tell me how your bombs are aimed," and he spent an occasional night in the brig, maintaining his usual cheerful calm, partly to avoid embarrassing his captors when the truth came out. Sorting things out at various times involved checks with headquarters, the intervention of an English officer on similar assignment, and a New York truck driver, whose primary assignment seems to have been to say, slowly and firmly in suitable dialect, "Ee's OK, see."[23]

Upon returning home Schwarzschild received many university job offers. "Very flattering but also very complicated to decide," he remembered in 1977. Rather than take a job as a department head ("I didn't trust that I had the judgment"), he decided instead to "go to the place with the best head."[24]

Meanwhile, Spitzer was being considered for the job of running Princeton's astrophysical department. Harlow Shapley, director of the Harvard College Observatory, had been acting as a mediator between Spitzer and Princeton. During negotiations Shapley asked Spitzer to outline in detail the conditions under which he would seriously consider coming to Princeton. In answer, Spitzer put together a long-range plan describing his intentions for the department and sent it to Shapley. Included in that plan was his desire to hire Martin Schwarzschild as a full professor. "I'd always been a great admirer of Martin Schwarzschild's since I first met him," Spitzer noted many years later. "He always seemed such an incisive, enthusiastic, clearly organized scientist."[25]

For Schwarzschild the feeling was mutual. "I wanted to be in a department led by Spitzer."[26] In 1947 he joined the Princeton astrophysical department under Lyman Spitzer's leadership.

Also part of Spitzer's master plan was his insistence that he and Schwarzschild alternately spend one semester every two years away from the university doing observational research. For years afterward they would each spend half a year at the Mt. Wilson observatory in Pasadena, California, using its 100-inch Hooker telescope.[27]

The 1954 lunch with Schwarzschild, Spitzer, and Van Allen took place immediately after Schwarzschild's most recent trip out west, where he had been working with, of all people, Richard Richardson, the astronomer and sometime science fiction author who in 1940 had written an article proposing the construction of a 300-inch telescope on the Moon for the science fiction magazine *Astounding Science Fiction*. The two men had been trying to photograph the convective turbulence on the surface of the Sun. Both of them had been very frustrated, however. As Schwarzschild explained during that lunch with Spitzer and Van Allen, "I complained bitterly about the hard fate of the astronomer sitting under this miserable atmosphere."

Schwarzschild remembered Van Allen laughing and saying, "Oh, you astronomers should just get off your traditional ways and send your telescopes up in balloons. We cosmic ray physicists have done it for a decade or two, with quite complicated instruments. You are just too ground-bound."[28]

The idea of using telescopes on balloons, which strangely enough had not occurred to either Spitzer or Schwarzschild, excited them both. Spitzer unfortunately couldn't spare the time for such a project, committed as he was to the Matterhorn project.

Schwarzschild in turn was not an experimentalist, and was doubtful he could do it. Over the next few months Spitzer pressed him, however. "Why don't you try?" he would say in his gentle but insistent manner.

Schwarzschild could not resist, and with Spitzer's help he spent the next four years building the first balloon-borne telescope, called Stratoscope.* While Schwarzschild ran the project, Spitzer did the fund-raising, getting the Office of Naval Research to finance the project. For the construction of the telescope Schwarzschild contracted a Connecticut company called Perkin-Elmer, known for building high-precision scientific and military optics. For its guidance system he hired what became Ball Brothers, later known for building some of NASA's best scientific and military satellites. For the balloon, he hired a balloon company in Minneapolis. "The whole setup," Schwarzschild remembered, "when you look from the present point of view, was fantastically primitive."[29]

Nonetheless, in the summer and fall of 1957, Schwarzschild's 12-inch balloon telescope made a handful of flights, taking tens of thousands of pictures. The first flight, on August 22, 1957, had a "hair-raising launch" according to Spitzer, though it successfully carried a dummy telescope to test the guidance system. The second flight, on September 25, took the balloon to 80,000 feet, where it took some 8,000 pictures of the Sun. A third flight in October was reconfigured to produce five slow scans of the Sun's surface.

Schwarzschild's results were mixed, but nonetheless exhilarating. "Mostly with nothing, but a few frames of entirely superior quality," Schwarzschild remembered. "[They] were the first off-the-ground astronomical [images]." The pictures showed for the first time the polygonal granulations that churn about on the Sun's surface. As noted by *Sky and Telescope,* this success "foreshadow[ed] many kinds of future observations in which the astronomer is on the ground while his equipment is taken above the atmosphere to where observing conditions are nearly perfect."[30]

Schwarzschild's project was part of what was to be one of the most important international scientific endeavors ever attempted, called the International Geophysical Year. Organized by scientists in the mid-1950s, the IGY intended to encourage researchers worldwide to simultaneously study "the fluid envelope of our planet—the atmosphere and oceans—over all of the Earth and at all heights and depths." The IGY's time period,

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* Ironically, Schwarzschild found out years later that his own father had attempted to do the same thing in Germany, using a Zeppelin.

from July 1957 through December 1958, was picked to correspond to the solar maximum in the Sun's eleven-year solar cycle, the period when the Sun's sunspot activity is at its most intense. As part of the event, the organizers not only called for global studies of the Sun, the weather, the Earth's magnetism, its aurora, and its geology, they also issued a challenge to the participants to build and launch the first artificial satellite.

As obvious and as enthusiastic as many of the United States' scientists were about the idea of orbiting a satellite, there was also a great deal of skepticism. Some worried that the general public would not understand the event and would somehow see it as dangerous. Others fretted about the cost, which was certainly several magnitudes greater than what the United States was spending to launch suborbital sounding rockets to do atmospheric research.

After several months of debate, scientists from a number of committees at both the National Research Council and the National Science Foundation eventually agreed to work together to convince the U.S. government to build a satellite. This decision was then followed by more negotiations, this time between these quasi-governmental academic organizations and the federal government. Finally, in late July 1955 the White House announced that the United States would launch a very small satellite, called Vanguard, as part of the IGY.[31]

From Spitzer's point of view, Vanguard was certainly a step in the right direction in his dream of building a space-based telescope. Nonetheless, Vanguard was very small, a sphere less than seven inches in diameter and weighing slightly more than three pounds. Moreover, the United States had no clear plans to do anything in space beyond Vanguard. Considering the skepticism that Spitzer had seen from astronomers about his ideas, it didn't appear that the construction of an orbiting space telescope would occur anytime in the near future.

Then, on October 4, 1957, everything changed. On that day, the Soviet Union—not the United States—proved to the world that a space satellite could be built. And they did it with a satellite that weighed seventy times more than Vanguard and was three and a half times bigger.

On that day they launched Sputnik.