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To my mentors in science,
William Gerace, Robert Naumann,
Martin Rees, and Kip Thorne

A SENSE OF THE MYSTERIOUS

EVER SINCE I WAS a young boy, my passions have been divided between science and art. I was fortunate to make a life in both, as a physicist and a novelist, and even to find creative sympathies between the two, but I have had to live with a constant tension in myself and a continual rumbling in my gut.

In childhood, I wrote dozens of poems. I expressed in verse my questions about death, my loneliness, my admiration for a plum-colored sky, my unrequited love for fourteen-year-old girls. Overdue books of poetry and stories littered my second-floor bedroom. Reading, listening, even thinking, I was mesmerized by the sounds and the movement of words. Words could be sudden, like *jolt,* or slow, like *meandering.* Words could be sharp or smooth, cool, silvery, prickly to touch, blaring like a trumpet call, fluid, pitter-pattered in rhythm. And, by magic, words could create scenes and emotions. When my grandfather died, I buried my grief in writing a poem, which I showed to my grandmother a month later. She cradled my face with her veined hands and said, “It’s beautiful,” and then began weeping all over again. How could marks on a white sheet of paper contain such power and force?

Between poems, I did scientific experiments. These I conducted in the cramped little laboratory I had built out of a storage closet in my house. In my homemade alchemist’s den, I hoarded resistors and capacitors, coils of wire of various thicknesses and grades, batteries, switches, photoelectric cells, magnets, dangerous chemicals that I had secretly ordered from unsuspecting supply stores, test tubes and Petri dishes, lovely glass flasks, Bunsen burners, scales. I delighted in my equipment. I loved to build things. Around the age of thirteen, I built a remote-control device that could activate the lights in various rooms of the house, amazing my three younger brothers. With a thermostat, a lightbulb, and a padded cardboard box, I contructed an incubator for the cell cultures in my biology experiments. After seeing the movie *Frankenstein,* I built a spark-generating induction coil, requiring tedious weeks upon weeks of winding a mile’s length of wire around an iron core.

In some of my scientific investigations, I had a partner, John, my best high-school friend. John was a year older than I and as skinny as a strand of 30 gauge wire. When he thought something ironic, he would let out a high-pitched, shrill laugh that sounded like a hyena's. John did not share my interest in poetry or the higher arts. For him, all that was a sissyish waste of calories. John was all practicality. He wanted to seize life by the throat and pull out the answer. As it turned out, he was a genius with his hands. Patching together odds and ends from his house, he could build anything from scratch. John never saved the directions that came with new parts, he never drew up detailed schematic diagrams, and his wiring wandered drunkenly around the circuit board, but he had the magic touch, and when he would sit down cross-legged on the floor of his room and begin fiddling, the transistors hummed. His inventions were not pretty, but they worked, often better than mine.

Weekends, John and I would lie around in his room or mine, bored, listening to Bob Dylan records, occasionally thinking of things to excite our imaginations. Most of our friends filled their weekends with the company of girls, who produced plenty of excitement, but John and I were socially inept. So we listened to Dylan and read back issues of *Popular Science.* Lazily, we perused diagrams for building wrought-iron furniture with rivets instead of welded joints, circuits for fluorescent lamps and voice-activated tape recorders, and one-man flying machines made from plastic bleach bottles. And we undertook our ritual expeditions to Clark and Fay's on Poplar Avenue, the best-stocked supply store in Memphis. There, we squandered whole Saturdays happily adrift in the aisles of copper wire, socket wrenches, diodes, oddly shaped metallic brackets that we had no immediate use for but purchased anyway. Clark and Fay's was our home away from home. No, more like our temple. At Clark and Fay's, we spoke to each other in whispers.

Our most successful collaboration was a light-borne communication device. The heart of the thing was a mouthpiece made out of the lid of a shoe polish can, with the flat section of a balloon stretched tightly across it. Onto this rubber membrane we attached a tiny piece of silvered glass, which acted as a mirror. A light beam was focused onto the tiny mirror and reflected from it. When a person talked into the mouthpiece, the rubber vibrated. In turn, the tiny mirror quivered, and those quiverings produced a shimmering in the reflected beam, like the shimmering of sunlight reflected from a trembling sea. Thus, the information in the speaker's voice was precisely encoded onto light, each rise and dip of uttered sound translating itself into a brightening or dimming of light. After its reflection, the fluttering beam of light traveled across John's messy bedroom to our receiver, which was built from largely off-the-shelf stuff: a photocell to convert varying intensities of light into varying intensities of electrical current, an amplifier, and a microphone to convert electrical current into sound. Finally, the original voice was reproduced at the other end. Like any project that John was involved in, our communication device looked like a snarl of spare parts from a junkyard, but the thing worked.

It was with my rocket project that my scientific and artistic proclivities first collided. Ever since the launch of *Sputnik* in October 1957, around my ninth birthday, I had been entranced with the idea of sending a spacecraft aloft. I imagined the blast-off, the uncoiling plume of smoke, the silvery body of the rocket lit by the sun, the huge acceleration, the beautiful arc of the trajectory in the sky. By the age of fourteen, I was experimenting with my own rocket fuels. A fuel that burned too fast would explode like a bomb; a fuel that burned too slow would smolder like a barbecue grill. What seemed to work best was a mixture of powdered charcoal and zinc, sulfur, and potassium nitrate. For the ignition, I used a flashbulb from a Brownie camera, embedded within the fuel chamber. The sudden heat from the bulb would easily start the combustion, and the bulb could be triggered by thin wires trailing from the tail of the rocket to the battery in my control center, a hundred feet away. The body of the rocket I built from an aluminum tube. The craft had red tail fins. It was beautiful. For a launching pad, I used a V-shaped steel girder, pointed skyward at the appropriate angle and anchored in a wooden Coca-Cola crate filled with concrete.

I invited my awed younger brothers and several friends from the neighborhood to attend the rocket launch, which took place one Sunday at dawn at Ridgeway Golf Course. John, who was not in the slightest a romantic and didn't see anything useful about rockets, elected to stay in his bed and sleep. But even so, I had a good audience. Because I had estimated from thrust and weight calculations that my rocket might ascend a half mile into space, some of the boys brought binoculars. From my control center, I called out the countdown. I closed the switch. Ignition. With a flash and a whoosh, the rocket shot from its pad. But after rising only a few hundred feet, it did a sickening swerve, spun out of control, and crashed. The fins had come off. With sudden clarity, I remembered that instead of riveting the fins to the rocket body, as I should have, I had glued them on. To my eye, the rivets had been far too ugly. How I thought that mere glue would hold under the heat and aerodynamic force, I don't know. Evidently, I had sacrificed reality for aesthetics. John would have been horrified.

Later, I learned that I was not the first scientist for whom beauty had ultimately succumbed to reality. Aristotle famously proposed that as the heavens revolved about the earth, the planets moved in circles. Circles because the circle is the simplest and most perfect shape. Even when astronomers discovered that the planets sometimes zigzagged in their paths, showing that they couldn't remain in simple orbits, scientists remained so enthralled with the circle that they decided the planets must move in little circles attached to big circles. The circle idea was lovely and appealing. But it was proved wrong by the careful observations of Brahe and Kepler in the late sixteenth and early seventeenth centuries. Planets orbit in ellipses, not circles. Equally beautiful was the idea, dating from the 1930s, that all phenomena of nature should be completely identical if right hand and left hand were reversed, as if reflected in a mirror. This elegant idea, called "parity conservation," was proven wrong in the late 1950s by the experiments proposed by Lee and Yang, showing that some subatomic particles and reactions do not have identical mirror-image twins. Contrary to all expectations, right- and left-handedness are not equal.

When my scientific projects went awry, I could always find certain fulfillment in mathematics. I loved mathematics just as I loved science and poetry. When my math teachers assigned homework, most other students groaned and complained, but I relished the job. I would save my math problems for last, right before bedtime, like bites of chocolate cake awaiting me after a long and dutiful meal of history and Latin. Then I would devour my cake. In geometry, I loved drawing the diagrams; I loved finding the inexorable and irrefutable relations between lines, angles, and curves. In algebra, I loved the idea of abstraction, letting x's and y's stand for the number of nickels in a jar or the height of a building in the distance. And then solving a set of connected equations, one logical step after another. I loved the shining purity of mathematics, the logic, the precision. I loved the certainty. With mathematics, you were guaranteed an answer, as clean and crisp as a new twenty-dollar bill. And when you had found that answer, you were right, unquestionably right. The area of a circle is πr^2. Period.

Mathematics contrasted strongly with the ambiguities and contradictions in people. The world of people had no certainty or logic. People confused me. My mother sometimes said cruel things to me and my brothers, even though I felt that she loved us. My aunt Jean continued to drive recklessly and at great speeds, even though everyone told her that she would kill herself in an automobile. My uncle Edwin asked me to do a mathematical calculation that would help him run the family business with more efficiency, but when I showed him the result he brushed it aside with disdain. Blanche, the dear woman who worked forever for our family, deserted her husband after he abused her and then talked about him with affection for years. How does one make sense out of such actions and words?

A long time later, after I became a novelist, I realized that the ambiguities and complexities of the human mind are what give fiction and perhaps all art its power. A good novel gets under our skin, provokes us and haunts us long after the first reading, because we never fully understand the characters. We sweep through the narrative over and over again, searching for meaning. Good characters must retain a certain mystery and unfathomable depth, even for the author. Once we see to the bottom of their hearts, the novel is dead for us.

Eventually, I learned to appreciate both certainty and uncertainty. Both are necessary in the world. Both are part of being human.

IN COLLEGE, I made two important decisions about my career.

First, I would put my writing on the back burner until I became well established in science. I knew of a few scientists who later became writers, like C. P. Snow and Rachel Carson, but no writers who later in life became scientists. For some reason, science—at least the creative, research side of science—is a young person's game. In my own field, physics, I found that the average age at which Nobel Prize winners did their prize-winning work was only thirty-six. Perhaps it has something to do with the focus on and isolation of the subject. A handiness for visualizing in six dimensions or for abstracting the motion of a pendulum favors an agility of mind but apparently requires little knowledge of the human world. By contrast, the arts and humanities require experience with life and the awkward contradictions of people, experience that accumulates and deepens with age.

Second, I realized that I was better suited to be a theorist than an experimentalist. Although I loved to build things, I simply did not have the hands-on dexterity and practical talents of the best students. My junior-year electronics project caught fire when I plugged it in. My senior thesis project, a gorgeous apparatus of brass fittings and mylar windows designed to measure the half-life of certain radioactive atoms, was sidelined on the lab bench instead of being installed in the cyclotron for a real experiment. I never did believe the thing would actually work. And apparently neither did my professor, Robert Naumann, who kindly gave me high marks for my endless drawings of top views and side views and calculations of solid angles and efficiencies. In various ways, I was making the self-discovery that I was destined to be a theorist, a scientist who worked with abstractions about the physical world, ideas, mathematics. My equipment would be paper and pencil.

It was in college, also, that I realized there were other young people as excited about science as I was. In my sophomore year, I came under the wing of a renegade assistant professor of physics named Bill Gerace. Gerace had had some vague disagreements with the powers that be and had responded by forming his own tiny university, a group of a half-dozen students who lectured one another on physics and worked on independent projects under Professor Gerace's supervision and constant encouragement. We were all given desks in Gerace's "office," a room in the dark basement of the physics building. For us chosen ones, that room was a palace. Many of the beauties of thermodynamics, wave functions, and other magical parts of physics first unfolded for me in that basement room. I will never forget how I was recruited to join this university within a university. Gerace, a lab instructor during my first physics course, walked up to me one day at the end of an experiment and furtively assigned me a theoretical problem not connected with the lab: if a frictionless bug sits on the outer rim of a frictionless clock, starting at the twelve o'clock position, and begins sliding clockwise, at what angle (or hour mark) will the bug fall off? When I brought in the answer the next day, Gerace got a big smile on his face and told me that I was a physicist.

A year or two after college, I had my first true experience with original research. It was an experience that I can compare only to my first love affair. At the time, I was twenty-two years old, a graduate student in physics at the California Institute of Technology. My thesis adviser at Caltech was Kip Thorne, only thirty himself but already a full professor. Kip had grown up in Mormon Utah but had completely acclimatized to the hip zone of California in the early 1970s. He sported long red hair, starting to thin, a red beard, sandals, loose kaftanlike shirts splotched with colors, sometimes a gold chain around his neck. Freckled, lean limbed, wiry. And brilliant. His specialty was the study of general relativity, Einstein's theory of gravity. In fact, there was at this time a renaissance of interest in Einstein's arcane theory because astronomers had recently discovered new objects in space, such as neutron stars, that had enormous gravity and would require general relativity for a proper understanding.

One of Kip's programs was to compare general relativity to other modern theories of gravity. And it was in that program that he assigned me my first research problem. I was supposed to show, by mathematical calculation, whether a particular experimental result required that gravity be geometrical. The known experimental result was that all objects fall under gravity with the same acceleration. Drop a book and a cannonball from the same height, and they will hit the floor at the same time, if air resistance is small. That result says something profound about the nature of gravity. By "geometrical" Kip meant that gravity could be described completely as a warping of space. In such a picture, a mass like the sun acts as if it were a heavy weight sitting on a stretched rubber sheet; orbiting planets follow along the sagging surface of the sheet. In the early 1970s, some modern theories of gravity, such as Einstein's general relativity, were geometrical. Some were not. To be "geometrical," to be equivalent to a bending of space, a theory had to have a particular mathematical form. So my project amounted to writing down on a piece of paper the equations representing a giant umbrella theory of gravity, a "theory of theories" that encompassed many different possible theories, next imposing the restriction that all objects fall with the same acceleration, and then finding out whether that restriction was sufficiently powerful to rule out all nongeometrical theories.

I was both thrilled and terrified by my assignment. Until this point in my academic life, my theoretical adventures had consisted mainly of solving homework problems. With homework problems, the answer was known. If you couldn't solve the problem yourself, you could look up the answer in the back of the book or ask a smarter student for help. But this research problem with gravity was different. The answer wasn't known. And even though I understood that my problem was inconsequential in the grand sweep of science, it was still original research. No one would know the answer until I found it. Or failed to find it.

After an initial period of study and work, I succeeded in writing down all the equations I thought relevant. Then I hit a wall. I knew something was amiss, because a simple result at an early stage in the calculation was not coming out right. But I could not find my error. And I didn't even know what kind of error. Perhaps one of the equations was wrong. Or maybe the equations were right but I was making a silly arithmetic mistake. Or perhaps the conjecture was false but would require an especially devious counterexample to disprove it. Day after day, I checked each equation, pacing back and forth in my little windowless office, but I didn't know what I was doing wrong. This confusion and failure went on for months. For months, I ate, drank, and slept my research problem. I began keeping cans of tuna fish in a lower drawer of the desk and eating meals in my office.

Then one morning, I remember that it was a Sunday morning, I woke up about five a.m. and couldn't sleep. I felt terribly excited. Something strange was happening in my mind. I was thinking about my research problem, and I was seeing deeply into it. I was seeing it in ways I never had before. The physical sensation was that my head was lifting off my shoulders. I felt weightless. And I had absolutely no sense of my self. It was an experience completely without ego, without any thought about consequences or approval or fame. Furthermore, I had no sense of my body. I didn't know who I was or where I was. I was simply spirit, in a state of pure exhilaration.

The best analogy I've been able to find for that intense feeling of the creative moment is sailing a round-bottomed boat in strong wind. Normally, the hull stays down in the water, with the frictional drag greatly limiting the speed of the boat. But in high wind, every once in a while the hull lifts out of the water, and the drag goes instantly to near zero. It feels like a great hand has suddenly grabbed hold and flung you across the surface like a skimming stone. It's called planing.

So I woke up at five to find myself planing. Although I had no sense of my ego, I did have a feeling of rightness. I had a strong sensation of seeing deeply into the problem and understanding it and knowing that I was right—a certain kind of inevitability. With these sensations surging through me, I tiptoed out of my bedroom, almost reverently, afraid to disturb whatever strange magic was going on in my head, and I went to the kitchen. There, I sat down at my ramshackle kitchen table. I got out the pages of my calculations, by now curling and stained. A tiny bit of daylight was starting to seep through the window. Although I was oblivious to myself, my body, and everything around me, the fact is I was completely alone. I don't think any other person in the world would have been able to help me at that moment. And I didn't want any help. I had all of these sensations and revelations going on in my head, and being alone with all that was an essential part of it.

Somehow, I had reconceptualized the project, spotting my error of thinking, and begun anew. I'm not sure how this rethinking happened, but it wasn't by going from one equation to the next. After a while at the kitchen table, I solved my research problem. I had proved that the conjecture was true. The equal acceleration of the book and the cannonball does indeed require that gravity be geometrical. I strode out of the kitchen, feeling stunned and powerful. Suddenly I heard a noise and looked up at the clock on the wall and saw that it was two o'clock in the afternoon.

I was to experience this creative moment again, with other scientific projects. But this was my first time. As a novelist, I've experienced the same sensation. When I suddenly understand a character I've been struggling with, or find a lovely way of describing a scene, I am lifted out of the water, and I plane. I've read the accounts of other writers, musicians, and actors, and I think that the sensation and process are almost identical in all creative activities. The pattern seems universal: The study and hard work. The prepared mind. The being stuck. The sudden shift. The letting go of control. The letting go of self.

I learned many things about science from Kip. One of the most important was the concept of the "well-posed problem." A well-posed problem is a problem that can be stated with enough clarity and definiteness that it is guaranteed a solution. Such a solution might require ten years, or a hundred, but there should be a definite solution. While it is true that science is constantly revising itself to respond to new information and ideas, at any moment scientists are working on well-posed problems.

I often think of Kip's idea of the well-posed problem as closely related to Karl Popper's notion of what makes a scientific proposition. According to Popper, who was an important early-twentieth-century British philosopher of science, a scientific proposition is a statement that can in principle be proven false. Unlike with mathematics, which exists completely within its own world of logical abstraction, you can never prove a scientific proposition or theory true because you can never be sure that tomorrow you might not find a counterexample in nature. Scientific theories are just simplified models of nature. Such a model might be mathematically correct, but its beginning premises might not be in sufficient accord with physical reality. But you can certainly prove any scientific theory false. You can find a counterexample, an experiment that disagrees with the theory. And, according to Popper, unless you can at least imagine an experiment that might falsify a theory, that theory or statement is not scientific.

In direct and indirect ways, Kip emphasized to his students that we should not waste time on problems that weren't well-posed problems. I have since come to understand that there are many interesting problems that are not well posed in the Popper or Thorne sense. For example: Does God exist? Or, What is love? Or, Would we be happier if we lived a thousand years? These questions are terribly interesting, but they lie outside the domain of science. Never will a physics student receive his or her degree working on such a question. One cannot falsify the statement that God exists (or doesn't exist). One cannot falsify the statement that we would be happier (or not happier) if we lived longer. Yet these are still fascinating questions, questions that provoke us and bring forth all kinds of creative thought and invention. For many artists and humanists, the question is more important than the answer. One of my favorite passages from Rilke's *Letters to a Young Poet* is this: "We should try to love the questions themselves, like locked rooms and like books that are written in a very foreign tongue." Science is powerful, but it has limitations. Just as the world needs both certainty and uncertainty, the world needs questions with answers and questions without answers.

Another thing I learned from Kip, more a matter of personal style, was generosity. Kip bent over backward to give credit first to his students. He would put his name last on joint papers, he would heap praise on his students at public lectures. Kip was well aware of his strengths, but he was modest at the same time, and he was deeply generous in his heart. I believe that he inherited these virtues from his own thesis adviser at Princeton, John Wheeler. Wheeler, in turn, absorbed much of his personal style from his mentor, the great atomic physicist Niels Bohr, in Copenhagen. In a sense, I was a "great-grand-student" of Bohr's.

Three Caltech professors served on my thesis committee, charged with examining me at my final thesis defense. Richard Feynman was one of the three. For some years, Feynman had taken an interest in Kip's students and, every couple of months, would go to lunch with us and pepper us with questions about the latest findings in gravitational waves or black holes or some other topic in general relativity. At my thesis defense, I stood at a blackboard in a small room while these guys sat comfortably and asked me questions. Feynman asked the first two questions. His first question was rather easy, and I answered it without too much trouble. His second question was just a little beyond my reach. I struggled with it; I went sideways and backwards; I circled around. Finally, after about twenty minutes of fumbling at the blackboard, I managed an answer. Feynman asked no more questions. Later, I realized that with his two questions he had precisely bracketed my ability. He had launched two artillery shells at me, one falling short, one long, and he knew exactly where I was in the intellectual landscape of physics.

I VIVIDLY REMEMBER a scene from sometime in 1975. It takes place during my two years as a postdoctoral fellow at Cornell. I am sitting on a couch in Edwin Salpeter's house. Ed, suffering from one of his recurring back problems, lies on the floor. From that low vantage, he is helping me think through a problem involving stars being ripped apart and consumed by a giant black hole. It is a theoretical problem, of course.

At this time, Ed would have been about fifty years old. He was widely regarded as one of the two or three greatest theoretical astrophysicists in the world. His most famous work, done in the 1950s, involved the theoretical recipe for how helium atoms in stars can combine to make carbon, and then heavier elements beyond that. It is believed that all of the chemical elements in the universe heavier than the two lightest, hydrogen and helium, were forged at the centers of stars. Ed and his colleagues showed how that process was possible. Among some of his other accomplishments, Ed calculated how many stars should be created in each range of mass—a sort of birth-weight chart for newborn stars.

When I first arrived at Cornell, in the fall of 1974, Ed immediately dragged me out to the tennis courts to find out what I was made of. I was a fair tennis player. After a number of exhausting matches over the season, we were approximately tied, but Ed could not refrain from quietly gloating whenever he beat me. And I could see that same gentlemanly but competitive edge in his science. He didn't like to lose.

On and off the tennis court, Ed dressed in tattered short-sleeve sports shirts. These, combined with his loafers and stylishly long hair and faint accent from his Austrian roots, gave him an air of casual elegance. But Ed was enormously serious about his physics. When he was talking about a physics problem, he would sometimes stop, turn his head, and just stare off into space for a few moments, and you knew that he was delving into deeper layers of thought.

What I found most brilliant about Ed was his physical intuition. He could visualize a physical problem and almost feel his way to the core of it, all in his head. This ability arose from his vast knowledge of physics and astronomy and his talent for making analogies from one subject to another. Many of the greatest scientists have had this talent for analogies. Planck compared the inside surface of a container to a collection of springs with different oscillation frequencies. Bohr compared the nucleus of an atom to a drop of liquid.

So we're in Ed's living room, me on the couch, Ed on his back on the floor, some kind of classical music floating in from the next room, and Ed draws an analogy between stars being swallowed by the big black hole and a drunk wandering on a street that has an uncovered sewer hole. If a star comes too close to the black hole it will be destroyed, just as if the drunk stumbles to the sewer hole he will fall in. Each star, in each orbit around the central black hole, is given a random jostle by the gravity of the other stars, just as the drunk takes a random step every second. Such random steps can lead a star, or a drunk, to fall into the hole. The stars bump about in two-dimensional "angular-momentum space," just as the drunk wanders around on a two-dimensional street. The critical question, Ed announces from the floor, is whether each random step of the drunk is bigger or smaller than the diameter of the hole. With this insight, I and the other postdoctoral fellow collaborating with me on the problem can now work out the details. The result will be a prediction for the Hubble Space Telescope, more than a decade away. Ed asks if I would please bring him a cup of tea. He has other things to think about this morning.

Some months later, I had a severe emotional upheaval with a different scientific project. I was working on the arrangement of stars in a globular cluster. A

Beethoven from the *Moonlight Sonata.* No one will ever write *The Tempest* except Shakespeare or *The Trial* except Kafka.

I loved the grandeur, the power, the beauty, the logic and precision of science, but I also ached to express something of myself—my individuality, the particular way that I saw the world, my unique way of being. On that day in the Cornell library, as I feverishly turned the pages of *Astrophysics and Space Science,* I learned something about science, and I also learned something about myself. I would continue following my passion in science, but I could no longer suppress my passion for writing.

FINALLY, IN THE EARLY 1980S, I began writing essays. For some years I had been publishing poems in small literary magazines. The essay gave me the greater flexibility I wanted. With an essay, I could be informative, poetic, philosophical, personal. And, at a time when most of my self-identity and confidence were still based on my achievements as a scientist, with the essay I could connect my scientific and artistic interests. I would come home in the evening, elated from a day of research at the Harvard-Smithsonian Center for Astrophysics, and ponder an essay.

One of my first essays concerned Joseph Weber, a distinguished professor of physics at the University of Maryland. Weber had pioneered the first gravitational wave detectors. He had also become somewhat of an outcast in the scientific community because he claimed to have seen gravitational waves when no one else could.

When you shake an electrical charge, it emits waves of electricity and magnetism that travel through space at the speed of light. Likewise, Einstein's general relativity predicted that when you shake a mass of any kind, whether electrically charged or not, it emits gravitational waves, waves of oscillating gravity that travel through space also with the speed of light. Hypothetically, the strongest sources of such waves would be cataclysmic cosmic events, such as the collision of black holes in space.

How does one observe a gravitational wave? When a gravitational wave strikes a

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