PROFILE: SUBRAHMANYAN CHANDRASEKHAR

Confronting the Final Limit

Clad in a dark, classically tailored suit and black shoes, Subrahmanyan Chandrasekhar approaches with a slow but fluid gait. He shakes my hand firmly, unsmiling; he has no need to ingratiate. Easing his lean frame into a chair, he slouches sideways and cocks his head, as if from this oblique angle his obsidian eyes can bore in on me better. What, precisely, do I want to talk about? he inquires. His voice still bears an Indian lilt, although he came here to the University of Chicago more than half a century ago.

I reply that I am interested in all aspects of his career, including his demonstration in the 1930s that stars above a certain mass—now known as the Chandrasekhar limit—undergo a catastrophic collapse. The finding, for which Chandrasekhar received, belatedly, the 1983 Nobel Prize, remains a cornerstone of modern astrophysics. I am also eager to hear his views on his latest object of study, Isaac Newton's *Philosophiae Naturalis Principia Mathematica* (*Mathematical Principles of Natural Philosophy*), the opus that laid the foundation for modern science.

CHANDRASEKHAR calls Newton's Principia, *which he has been studying, an achievement with "no parallel in science at any time."*

Chandrasekhar says he is completing a book on the *Principia*, and he is not sure he wants to preview it. I assure him that since my article will be only two pages long, it cannot discuss the *Principia* in detail. His eyes grow darker still. "You think you can summarize Homer's *Odyssey* in two pages?" he snaps, jabbing first one, then both, impossibly long forefingers at me. "You think you can write about the Sistine Chapel in two pages?" His voice quavers with incredulity, disgust. "If you write only two pages, I don't think it matters very much if you talk to me."

Somehow the interview lurches forward, and Chandrasekhar, whom friends cali Chandra, slips into the charming persona that colleagues had described. He dispenses jokes, anecdotes and aphorisms, as well as smiles and laughter, generously. But in that moment of anger, he has revealed the incompressible passion—not only for scientific truth but for beauty, which in Chandrasekhar's mind are fused—at his core. It is this quality that helped Chandrasekhar overcome an enormous blow early in his career to become one of the world's most distinguished and productive physicists.

The trait may also explain why Chandrasekhar, who at 83 is still legendary for his work habits, exudes a certain restlessness. In *Chandra*, a biography published in 1991, the physicist Kameshwar C. Wali suggests that a clue to Chandrasekhar's character can be found in a striking photograph hanging in his office. It shows a man climbing a ladder that leans against some vast, abstract structure. Like the ascending man, Wali says, Chandrasekhar is "constantly aware of how much more there is to know" and of his own inadequacies.

Chandrasekhar was nurtured on ambition. His mother, in addition to raising 10 children, found time for such pursuits as translating Henrik Ibsen's *A Doll's House* into Tamil. His father was a government official whose younger brother, the physicist C. V. Raman, received the 1930 Nobel Prize. Not surprisingly, then, Chandrasekhar became a star student of physics and mathematics at the Presidency College in Madras.

In 1930 he left India for the University of Cambridge, and since then he has returned to his native land only for visits. Chandrasekhar admits he sometimes wonders how his career would have unfolded had he remained in India. Like Raman, his uncle, he might someday have presided over his own institute, but he then would have become enmeshed in the arcane politics of India's scientific establishment. "I have one advantage here" in the U.S., Chandrasekhar says. "I have enormous freedom. I can do what I want. Nobody bothers me."

At Cambridge, Chandrasekhar began applying his already broad knowledge of quantum mechanics and relativity to the question of how stars evolve. Among his mentors was Sir Arthur Eddington, whose influential text on astrophysics had lured Chandrasekhar to that subject. Chandrasekhar's theoretical forays soon led him to an unsettling conclusion. Most astronomers believed that when stars exhausted their store of nuclear fuel, they settled into interminable old age as small, dense white dwarfs. Chandrasekhar's calculations revealed that in stars whose masses were more than 1.4 times that of the sun, gravity would overcome the outward, repulsive pressure of electrons and trigger a collapse into states of matter even denser than that of white dwarfs.

Astronomers eventually unraveled the

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strange destinies of stars whose masses transcend the Chandrasekhar limit: after erupting into supernovae, their cores implode into spheres of compacted neutrons called neutron stars (one cup of which out weighs Mount Everest) or into infinitely dense black holes. But acceptance of Chandrasekhar's insight was slow in coming. The reason was that in 1935, immediately after the 24-year-old Chandrasekhar presented his theory before the Royal Astronomical Society, Eddington himself stood to ridicule it as self-evidently wrong, an example of reductio ad absurdum. Eddington had previously given his protégé no inkling of his views.

Chandrasekhar insists that at the time he harbored no ill feelings toward Eddington; they even remained friends. Eddington's repudiation of Chandrasekhar's theory nonetheless played a role in his decision in 1937 to leave England for the University of Chicago, where he has remained. He also left behind the subject of collapsing stars, but not before he had written a book. "I simply decided, well, I will write a book and present my idea, leave the subject and go on to other things. And that's all happened, you see."

Although brought on by trauma, this pattern—total immersion in a subject followed by an abrupt swerve toward "other things"—was to become characteristic of Chandrasekhar. After his stellar evolution phase, he spent five years considering the motion of stars within a galaxy, demonstrating that stars exert a kind of friction on one another through their gravitational interactions. From 1943 through 1950 he contemplated the transfer of radiation within stellar and planetary atmospheres. Then came periods devoted to the properties of fluids and magnetic fields and to ellipsoids, geometric objects whose properties have proved useful for understanding galaxies. Between 1974 and 1983 he explored black holes, coming back full circle, in a sense, to the work that had launched his career.

The books that Chandrasekhar wrote at the close of each period were instant classics, praised for their breadth and clarity. Chandrasekhar says he has always sought to present his findings in as elegant, even literary, a form as possible. "I select some writers in order to learn," he confides. "For example, I read Henry James or Virginia Woolf, and I don't simply read the text as a novel; I see how they construct sentences, how they construct paragraphs, how one paragraph goes into another and so on."

Too few scientists write well or even carefully, according to Chandrasekhar: "You take any volume of the *Astrophysical Journal* or the *Physical Review*, turn to the middle of it, put your hand on a paragraph. You are sure to find a mistake, either in style or grammar or something." Chandrasekhar sought to encourage good writing during the 20 years he served as editor of the *Astrophysical Journal*, the premier publication of his field. "I will tell you a malicious statement I used to make" to authors, he remarks, grinning. "I would say, 'Your paper is scientifically correct, but I wish you would ask your colleague in the English department to read it.'"

Chandrasekhar's latest epoch began when he was invited to contribute a paper to a meeting held in 1987 to celebrate the 300th birthday of the *Principia*. Chandrasekhar had long hoped to delve into the *Principia;* he bought an English translation of the book (which Newton wrote in Latin) decades ago. But he had always been too busy staking out his own territory—and, he now believes, too intellectually immature for serious study of the difficult work. He notes that in order to understand Newton's somewhat "secretive" and elliptical style, "you must read line by line."

He decided early on that rather than assessing Newton secondhand, through commentaries, he would absorb the *Principia* unmediated. More specifically, he would read a proposition and then, before going on to Newton's proof, would try to derive his own. Chandrasekhar points out that although he has 300 extra years of knowledge at his disposal, in virtually every case his proofs fell short of Newton's.

Reading Newton became for Chandrasekhar a sustained epiphany. "The view of science that he exhibits, the clarity with which he writes, the number of new things he finds, manifest a physical and mathematical insight of which there is no parallel in science at any time." It is common knowledge that Newton invented calculus as well as seminal theories of gravity and optics. But Chandrasekhar argues that the *Principia* contains other achievements that have been overlooked. For example, Newton set forth a theory of gyroscopes, which were not invented for another 200 years. He was the first scientist to note that knowledge of the initial conditions of a system should provide one with knowledge of its entire future, an insight usually credited to Laplace. He invented a theory of image formation generally ascribed to Lord Kelvin.

Chandrasekhar is as entranced by the style of the *Principia* as he is by its substance. He compares Newton's prose to that of Henry James, who was similarly fond of long, complex sentences. To demonstrate his point, Chandrasekhar fetches his massive, black copy of the *Principia* and reads: "We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances. To this purpose the philosophers say that Nature does nothing in vain, and more is in vain when less will serve; for Nature is pleased with simplicity, and affects not the pomp of superfluous causes." Chandrasekhar looks up and exclaims, his voice cracking, "Isn't that a beautiful sentence? Absolutely!"

Chandrasekhar likens reading Newton to what were for him equally awe-evoking experiences: gazing at the ceiling of the Sistine Chapel, watching Sir John Gielgud play Hamlet or hearing Arturo Toscanini conduct Beethoven's Ninth Symphony. Indeed, as great as Newton's reputation is, it is not great enough to satisfy Chandrasekhar. "Newton is not one of the two or three greatest scientists. He is one of the two or three greatest intellects, ever, in any subject. If you want to compare Newton to anybody, you have to go outside science."

Chandrasekhar has already sent more than 20 chapters of his planned 30-chapter book to his publisher, and he hopes to complete it this spring. Has he given thought to some new project beyond that? "No, that's the end," he says abruptly. "I don't expect to do science after I finish work on the *Principia*." When I express surprise that someone who has been so consistently productive could simply cease working, he says heatedly, "Obviously I can go on doing work of a quality that is below my standards, but why do that? So the time must come when I say, 'Stop.'"

I am reminded of an essay, published in *Nature* in 1990, in which Chandrasekhar describes the creative life as a constant striving against "one's inherent and often insurmountable limitations." He concludes the essay with lines from a poem by T. S. Eliot: "It is strange, isn't it/That a man should have a consuming passion/To do something for which he lacks the capacity?"

Yet there are consolations, even for a seeker past his prime. Chandrasekhar recollects that G. H. Hardy, in his classic memoir *A Mathematician's Apology*, called an old mathematician whose ideas have run dry "a pathetic person." Hardy consoled himself, particularly when forced to endure boring, second-rate colleagues, with the knowledge that he had once communed with some of the greatest intellects of his age. Chandrasekhar confesses that he has cultivated a similar habit when he finds himself in "tiresome" situations: "I think to myself, 'I have been in the company of Newton.'"

—*John Horgan*