DR S. CHANDRASEKHAR

The Nobel Astrophysicist

DURING a long sea voyage to Europe in 1921 Indian physicist C.V. Raman wondered why the sky was blue. The answer to this deceptively simple question, when he finally unravelled it, was promptly dubbed the Raman Effect and won him the 1930 Nobel Prize for physics. But in the year Raman collected his Nobel Prize, his nephew Subrahmanyan Chandrasekhar made the same boat trip to England to enrol in Trinity College, Cambridge. Like his uncle before him, Chandrasekhar spent the journey absorbed in deep thought. As he sat on the deck the 21-year-old gazed at the stars and wondered about their ultimate evolution and fate.

Three years later at Cambridge, he thought he had found a complete theory explaining the birth and death of stars. But the world scoffed at his theory and it was quickly forgotten. But not for long. The theory was revived in the early 1950s, accepted by astrophysicists all over the world and entered into textbooks. And another 30 years later it won the author the award that every scientist covets: a Nobel Prize.

Regular Routine: Chandrasekhar, who is now an American citizen, shares this year's Nobel Prize for physics with fellow American William Fowler of the California Institute of Technology, received the news of the award at his modest apartment in Chicago's south side. "It sure was a birthday gift," the University of Chicago professor told INDIA TODAY in an exclusive telephone interview. "It was related to my work I did in the 1930s." Chandrasekhar, the first astrophysicist ever to win a Nobel Prize, had just turned 73, an age at which most scientists have retired. But not Chandrasekhar, who only a few months ago finished his latest book—"my best," he says—an eight-year project, while still recovering from a heart attack and open heart surgery. Asked what makes him tick he said: "I keep a regular routine of studying, reading and thinking about problems."

"Thinking about problems," as he modestly terms it, has in fact been his forte since his youth. At 19, while still a student at Presidency College, Madras, Chandrasekhar produced *Compton Scattering and New Statistics*, which was published in the proceedings of the Royal Society in 1929. Soon he became fascinated by the study of stars, his interest kindled by the British astronomer Arthur Eddington's classic book on the subject that he had won as prize in a contest.

Chandrasekhar: belated award

G. SRINIVASAN

By the time he set out for Cambridge on a government scholarship, he knew enough about the prevailing stellar theory to realise some of its glaring deficiencies. For instance, the theory simply ignored the fact that electrons inside a collapsed star were moving at the speed of light and hence must be governed by the laws of Einstein's Special Theory of Relativity. Chandrasekhar thought that the existing theory—shaped by Milne, Eddington, British physicist Ralph Fowler and others—would be quite different if relativistic corrections were incorporated into it. And it was these ideas that were whirling about in his mind as he gazed at the stars during his voyage to England. Continuing his theoretical work at Cambridge he made some startling findings.

Novel Ideas: Chandrasekhar was barely 24 when he presented his theory (*see box*) at the Royal Astrophysical Society meeting in London on January 11, 1935, before an illustrious audience that included his mentor, Eddington. In a nutshell his theory stated that dying stars have a critical mass that is 1.4 times the mass of the sun. Stars whose mass is less than this critical mass, after exhausting all their nuclear fuel, collapse due to gravity into a dense mass called the "white dwarf." But stars heavier than the critical mass simply go on collapsing beyond the dwarf star stage getting denser and denser and smaller and smaller. Such objects are today known as black holes and the critical mass has gone into textbooks as "Chandrasekhar's Limit."

INTERVIEW

"Birthday Gift"

NOBEL laureate Subrahmanyan Chandrasekhar gladly answered questions in an exclusive telephone interview with INDIA TODAY *from his Chicago residence. He, however, chose to avoid questions about whether he had hoped to win the Nobel Prize, whether his uncle, the late C.V. Raman, inspired his work, or whether he ever thought of returning to India. Excerpts from the interview:*

Q. ***You have won the Nobel Prize for physics for the work you did in your 20s. How did you feel about it?***

A. Well, I must say it was a birthday gift.

Q. ***Can you say in a few words how your discovery has helped in improving our understanding of the universe?***

A. I cannot do that in a few words. I can say that a number of astrophysical discoveries have resulted in the last 10 years. The enormous developments that have taken place in General Relativity have played a major role in the discovery of pulsars, X-ray stars and so on.

Q. ***You are the second India-born American after Hargobind Khurana to win the Nobel Prize. Why do Indian scientists have to go to the US to become worthy of the Nobel Prize?***

A. I can only speak for myself. I left India soon after graduation and have been working abroad ever since. The first time I visited India was 16 years after I left the country. I have had a number of Indian students working with me. Some of them have in fact gone back to work in India.

Q. ***At your age many scientists are retired or enjoy emeritus title. What is the secret of your professional longevity?***

A. There is nothing secret about it. I can only say I keep reading, studying and thinking about problems. Only a few months ago my latest book came out, on black holes.

Q. ***After your uncle, the late C.V. Raman, no scientist working in India has received a Nobel Prize. Is it because the scientific atmosphere in India is not conducive to research?***

A. I was in India in 1961, in 1968 and again in 1982. I must say the scientific atmosphere in India has enormously improved between 1961 and 1982. There is no doubt about it.

Fifty years ago when Chandrasekhar put forward his theory, nobody believed it. Under the prevailing theory of the time all stars irrespective of their final mass ended up as dwarf stars. Eddington described Chandrasekhar's critical mass theory as "outlandish". In the same meeting Eddington said that nature would not permit a star to keep on radiating and contracting. "It is absurd."

Eddington's international stature and influence were such that even physicists, who believed that Chandrasekhar was right, did not dare to counter him publicly. Says Chandrasekhar: "Eddington made a fool of me. I was distraught. I did not know whether to continue my career." In 1931, he quit Cambridge and joined the University of Chicago where he put his theory into a book, *Introduction to the Study of Stellar Structure*, and then stopped worrying about it. He turned to other problems: the scattering of light, behaviour of hot fluids in magnetic fields, stability of rotating objects and finally to black holes.

Increased Importance: As the Nobel Committee in its citation said, Chandrasekhar was honoured for "his theoretical studies on the physical processes of importance to the structure and evolution of stars". It was the work he did in his 20s. But why this belated award? Says Yash Pal, well-known space scientist who knows Chandrasekhar quite well: "The work done by Chandrasekhar is finding more relevance today than ever before. We use his equations in space research, remote sensing, and modern astronomy. In fact, there is no field in which some or other of his discoveries are not used." Jayant Narlikar, a renowned cosmologist at the Tata Institute of Fundamental Research in Bombay, says Chandrasekhar deserved the prize years ago but adds that "it is better late than never". Chandrasekhar himself never set his sights on the Nobel Prize. In an interview to *Science* magazine he said: "My motive has not been to solve a single problem, but to acquire a perspective of an entire area."

In fact, astrophysics as it is understood today owes its development to the entirely new perspective given to it by Chandrasekhar. Neutron stars—objects made entirely of neutrons—and black holes which gobble up anything nearby but do not allow even light to escape, are all now interpreted in terms of Chandrasekhar's famous Critical Mass theory.

Chandrasekhar was born on October 19, 1910, in Lahore. He met his wife Lalitha when both were physics students in Madras University. He considers himself an atheist but in his interview to *Science*, he admits that he sometimes wonders about the Hindu tradition of sanyas. Considering Chandrasekhar's penchant for work it is unlikely that he will ever try to follow such a course—especially as he has already begun studies on a new field: cosmology.

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Simple Life-style: Chandrasekhar is respected by everyone who comes into contact with him not only for his intellect but for his simplicity and friendliness. "He is a marvellous man," says F.C. Auluck, a former Delhi University physics professor. "When I was in Chicago I wanted to call on him. He said 'come home'. It was an unearthly hour, about midnight. Sure enough, he was there waiting for me, fresh and smiling." And teaching was Chandrasekhar's passion. Even in the severest Chicago winter he used to drive to university to take a class of only two students. The students—Yang and Lee—both later received the Nobel Prize in physics.

Though the Nobel Prize climaxed his 50 years of work in physics, Chandrasekhar has a string of other honours and medals. At 36, he became the distinguished service professor of physics. In 1952 he became editor of the prestigious *Astrophysical Journal*. The same year he was awarded the Bruce Medal of the Astronomical Society of the Pacific. He received the gold medal of the Royal Astronomical Society (1953), the Rumford Medal of the American Academy of Arts and Sciences (1957) the Royal Medal of the Royal Society, London (1962), the National Medal of Science, US (1967) and the Draper Medal of the US National Academy of Science (1971). Chandrasekhar has also delivered the 1968 Nehru Memorial Lecture at New Delhi. He last visited India in 1982. He plans to make another visit soon but said, "it will be a private visit, with my family."

THE THEORY

Cosmic Death

THE EXPRESSION "Chandrasekhar's Limit" has been in use in astrophysics since the early '30s when Chandrasekhar determined the minimum mass of a dying star enabling it to survive. The death of a star is a chilling cosmic phenomenon, marked by its swelling into a "red giant", its subsequent shrinking into a "white dwarf", and, in cases, its ultimate obliteration into a pulsar or as a "black hole".

Stars are constantly collapsing as a result of their own gravitational force. The collapse, in its turn, triggers thermonuclear explosions inside them, and the ensuing energy counteracts the gravitational pull, creating a state of equilibrium—till the nuclear furnace uses up all fuel available in the star's core. In the process hydrogen atoms are converted into helium. In the case of heavy stars, even helium is transformed into carbon and oxygen. The nuclear alchemy stops with everything changing into iron, an element that releases no energy.

As the furnace cools off, the force of gravitation again reigns unchecked, and the star condenses into a dense, dazzling ball. It still dazzles because the electrons, freed from atoms, keep moving; but the star shrinks to several thousandth part of its original radius. It is then regarded as the "white dwarf". Chandrasekhar's main area of enquiry was the fate of the white dwarfs and their further evolution.

In doing so, he combined the principles of quantum mechanics with the laws guiding the properties of particles that move quickly. Studying the behaviour of electron flow, he plotted the correlation between the radii of collapsed stars and their masses, on a curve.

The curve showed that electron pressure could counteract gravitation only as long as the mass of the star did not exceed 1.44 times that of the Sun: the Chandrasekhar Limit. If the star's mass is less than this level, it can carry on as a white dwarf. Stars about four times the mass of the Sun, change into pulsars, or neutron stars. However, the heavier ones have no defence against the gravitational pressure. In that case, matter is ultimately squeezed out of existence, giving rise to black holes. Chandrasekhar argues that if the Earth were to shrink to a radius of 2.5 km, it would become such a black hole, permitting no light to escape from it.