OBITUARY

# Subramanyan Chandrasekhar (1910–95)

SUBRAMANYAN Chandrasekhar, known to the world as Chandra, died on 21 August 1995. He is best known for his discovery of the upper limit to the mass of a white dwarf star, for which he received the Nobel Prize in Physics in 1983.

Chandra came from a highly educated South Indian family. His father, C. S. Ayyar, was a civil servant, attaining a high position with the Indian railways. The Ayyars had three sons and five daughters of whom Chandra was the oldest son, born on 19 October 1910 in Lahore, then part of British India. In 1916 the family moved to Madras where Chandra grew up.

Chandra was a brilliant student. At 15, he entered Presidency College, the most prestigious in Madras; in 1927 he started their physics honours course, graduating in 1930 at the top of his class. He read far beyond the curriculum, for instance about Fermi statistics, where he was most intrigued by Ralph H. Fowler's work on the constitution of white dwarf stars. This subject inspired him to write his first scientific paper, "Compton Scattering and the New Statistics", which was published in the *Proceedings of the Royal Society* in 1928. Upon graduation, on the basis of this paper, he was accepted as a research student by Fowler at the University of Cambridge.

He left Bombay on a boat on 31 July 1930. On the voyage, after overcoming his seasickness, he remembered Fowler's paper and decided to combine it with his knowledge of special relativity theory. To his great surprise, he found that this combination predicted that white dwarfs could only exist up to a certain limiting mass which depended chiefly on fundamental constants such as $h$, $G$ and the mass of the hydrogen atom; the mass was about 1.45 times the mass of the Sun. England's two leading astrophysicists, Eddington and Milne, could not believe this result, and neither of them would recommend Chandra's paper for publication by the Royal Society. So Chandra sent it to the *Astrophysical Journal* in America, which published it in March 1931.

Chandra worked hard as a research student, and after he had taken his Ph.D., he was (to his great surprise) elected a fellow of Trinity College. Now feeling relaxed and more confident, he returned to the problem of white dwarfs. By a more complete calculation, he confirmed his earlier result: there is an upper limit to the mass of a white dwarf. He was invited to give a talk on this subject at the Royal Astronomical Society in January 1935. But after his lecture, Eddington stood up and rejected Chandra's results, not by scientific argument but by ridiculing the combination of special relativity theory with quantum statistics. Chandra was devastated.

Of course, Eddington was wrong. But his resistance to Chandra's mass limit was understandable: his life's work had been to show that every star, whatever its mass, had a stable configuration. It was generally (and correctly) believed that white dwarfs were the end stage of stellar evolution, after their energy source was exhausted. Why should there be a limit to the mass of a star in its old age? Chandra appealed to physicists he knew—Rosenfeld, Bohr, Pauli. Unanimously, they decided that there was no flaw in his argument. But it took decades before the Chandrasekhar limit was accepted by the astrophysics community.

The paradox that 'normal' stars can exist with any mass whereas white dwarfs can only exist up to 1.45 solar masses is now understood as follows. Stars, in their evolution, go through a giant stage in which their radius may be hundreds of times larger than originally. In this stage, the atoms at the surface are not strongly held by gravity, while there is strong radiation pressure from the inside. Some atoms, especially hydrogen, are blown off and the star gradually loses mass. Theory shows that stars up to 8 solar masses lose mass in this manner, ending up below the Chandrasekhar limit. None of this was known in 1935.

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The limit also affects stars heavier than 8 solar masses. Matter in their central core evolves to iron by successive nuclear reactions. At this point, no further nuclear energy can be obtained, just as in white dwarfs. When the iron core grows to the Chandrasekhar mass, it collapses by gravitation into a neutron star, and the rest of the star is expelled, giving a type II supernova. Some white dwarfs accrete matter from the outside, and when their mass has grown to the Chandra limit, they also become supernovae, in this case type Ia. Chandra's theory is basic to much modern astrophysics.

Chandra had to look for a more permanent position, and accepted an offer from Yerkes observatory, part of the University of Chicago with which he remained associated for the rest of his life — first at Yerkes, later in Fermi's Research Institute on the main university campus. Before starting work there in January 1937, he made an extensive visit to India and married Lalitha, his old friend from college days.

Chandra was an enthusiastic teacher who attracted students from all over the world. By the time of his retirement, he had guided over 50 students to their Ph.D.s. His own research covered nearly all branches of theoretical astrophysics; in his Nobel lecture, he said that his life's work fell into seven periods. At the culmination of each period, Chandra published a book collecting the insights he had gained; each covers its subject very thoroughly. *The Mathematical Theory of Black Holes* (1983) is truly formidable.

Chandra was a great supporter of Gandhi. But during the Second World War, he felt victory over Nazi Germany was the most important goal. Seeing it as his duty to contribute to the American war effort he began in 1943 to work half-time at the Aberdeen Proving Ground on shock waves. Later, he was invited to join the Los Alamos laboratory but, because of lengthy clearance problems, this did not come to pass. His feeling of duty was despite many indignities that he and Lalitha suffered because of their dark skin. Nevertheless, they felt American, and in 1953 were naturalized as American citizens, feeling their life would continue to be in America. This made Chandra's father very unhappy. He had tried repeatedly to get a suitable position for Chandra in India. But even if he had found one, what could have replaced the intellectual stimulation in America?

A year earlier, in 1952, Chandra had felt another call of duty. He believed there should be a national journal for astrophysics. Up to that time, nearly every major department of astronomy had its own publication. By long negotiations, he persuaded the American Astronomical Society and the University of Chicago jointly to publish the *Astrophysical Journal*, and Chandra, at great sacrifice of his scientific output, became its editor. In his 19 years as editor, Chandra transformed the *Astrophysical Journal* from a local publication into a world leader. He was, in his own words, dictatorial, and many astrophysicists complained because their papers were rejected. To continue at least some research, he rigorously enforced office hours: if a scientist phoned after the appointed closing time, he would answer, "The office of the *Astrophysical Journal* is closed."

I was always impressed by the depth and sophistication of Chandra's mind, and its capacity for retention which showed in his writings and speeches on any topic. His style was informed by the British authors of the late nineteenth and early twentieth centuries, and by Shakespeare. It was a pleasure to listen to one of his talks. In addition to style, he had the most perfect upper-class English accent I have heard.

Chandra was a first-rate astrophysicist and a beautiful and warm human being. I am happy to have known him.

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