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The legacy of S Chandrasekhar (1910–1995)

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Abstract. Subrahmanyan Chandrasekhar, known simply as Chandra in the scientific world, is one of the foremost scientists of the 20th century. In celebrating his birth centenary, I present a biographical portrait of an extraordinary, but a highly private individual unknown to the world at large. Drawing upon his own "A Scientific Autobiography," I reflect upon his legacy as a scientist and a great human being.

Keywords. White dwarfs; Chandrasekhar limit; relativistic degeneracy.

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1. Introductory remarks: Man on the ladder

When I stepped into Chandra's office for the first time in 1979, I was immediately intrigued by a photograph that faced him from the wall opposite his desk. As I stood looking at it, Chandra told me the following story. He had first seen the photograph on the cover of a *New York Times Magazine* and had written to the magazine for a copy (figure 1). He was referred to the artist, Piero Borello. Borello replied that Chandra could have a copy, even the original, but only if he cared to explain why he wanted it. Chandra responded:

"What impressed me about your picture was the extremely striking manner in which you visually portray one's inner feelings towards one's accomplishments: one is half-way up the ladder, but the few glimmerings of structure which one sees and to which one aspires are totally inaccessible, even if one were to climb to the top of the ladder. The realization of the absolute impossibility of achieving one's goals is only enhanced by the shadow giving one an even lowlier feeling of one's position."

Chandra's explanation could not have expressed more vividly what the picture portrays visually – the essence of the eternal quest for knowledge: its triumphs and frustrations, and its limitations, as well as one's own personal awe before the unknown.

For over six decades, Chandra pursued research and teaching, and with prolific contributions to physics, astrophysics and applied mathematics, he became and continues to be a legendary figure. His work brought him a measure of recognition attained by only a few. Yet, Chandra, I knew, embodied the symbolic man on the ladder in the Borello photograph, constantly aware of his limitations and remain unaffected by the outward

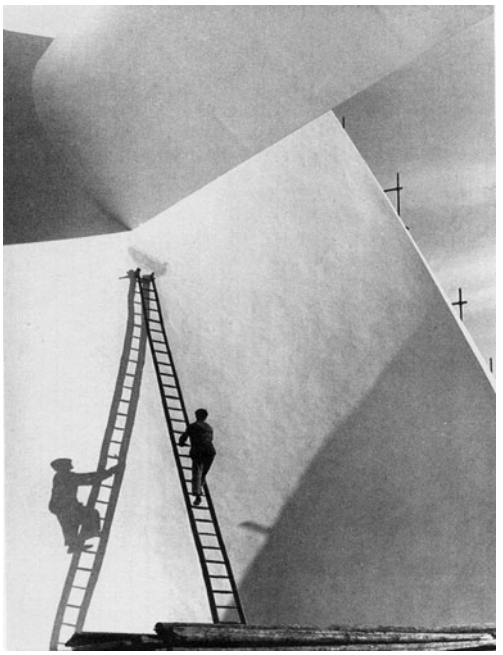

Figure 1. An Individual's View of the Individual (Man on the Ladder), by Piero Borello.

symbols of success. The prizes, medals, awards, honorary degrees, and memberships in academic societies seemed instead to leave him with a vague sense of discomfort and an added responsibility, a distortion from his science and creative pursuits.

2. The simple and true: The legacy

- One of the foremost scientists of the 20th century.
- A dedicated and charismatic teacher who guided the research of some 50 student from many parts of the world, many of whom have become and are among the notably prominent scientists in their fields.
- Served as the sole editor of the *Astrophysical Journal* for nearly 20 years and was chiefly responsible for making it the foremost Journal of this kind in the world.
- A man of two cultures; the sciences and humanities
  His major scientific works comprise seven volumes of *Selected Papers* published by the University of Chicago Press and seven monographs. His general, semi-popular essays exploring aesthetics and motivations in science and some historical biographical articles are collected together in the book *Truth and Beauty*, also published by the University of Chicago Press.
- Although he lived most of his life abroad, India was always in his mind. He kept strong associations with institutes in India and influenced many young and upcoming scientists from India.

Figure 2. A product of three widely different countries (Courtesy of Professor Roger Blandford).

Chandra maintained a life-long interest in perpetuating Srinivasa Ramanujan's memory. At G H Hardy's request, he went to great troubles in 1936 to secure a photograph of Ramanujun, the negative of which has served as the basis of all photographs, paintings, and etchings of the genius. In the late 1940s, he was instrumental in founding the Ramanujan Institute of Mathematics in Madras with the financial help of a former classmate, Alagappa Chettiar, who prospered as an entrepreneur and became a well-known philanthropist. After Chettiar's death, when reports reached Chandra about the imminent death of the Institute, he promptly wrote to Jawaharlal Nehru. With Nehru's personal intervention, the institute survived. The institute owed a great deal to Chandra and the mathematician Andre Weil for its continued existence after Nehru until its merger with the mathematics department of Madras University in 1967.

- Chandra was the product of three widely different countries: India, the land of his birth, with its ancient traditions and culture, which had undoubtedly influenced his childhood and youth; Cambridge and England, the land of the colonial masters, where his research mushroomed and matured; and finally, America, his adopted homeland, where he continued his research and teaching career till the end of his life (figure 2).

3. Beginnings: Lahore and Madras 1910–25

Chandra was born in Lahore, Pakistan (then a part of colonial British India). His father, Chandrasekhara Subrahmanyan Ayyar was in the British government service, as the deputy auditor-general of the Northwestern Railways. Chandra was the first son and the third child in a family of four sons and six daughters. His mother was a remarkable woman of great talent and intellectual attainments. As a mostly self-taught person, she was intensely ambitious for her children and played a pivotal role in Chandra's pursuit of a career in pure science.

Chandra's early education was at home under the tutelage of his parents and private tutors. When he was 11 years old and the family had permanently settled in Madras (now Chennai), he began his regular schooling at the Hindu High School in the city's Triplicane district. Chandra found the formal school neither easy nor pleasant. His education at home under private tutors had allowed him the freedom to study what he liked (mainly English and arithmetic). Now he was suddenly required to study history, geography, and general science and was subjected to periodic examinations. It was a disappointing first year, but looking ahead at the curriculum of the following year,which included algebra and geometry, he was excited enough to continue. Without waiting for the classes to begin he got the books and studied on his own during the summer vacation. By the time he got to the fourth form, he knew all the geometry and all the algebra they were going to teach, and in fact more. He kept this up in the following three vacations and did extremely well in high school and became a freshman at the Presidency College in Madras when he was only 15 years old.

4. Presidency College (1925–30)

Chandra's freshman and sophomore years (1925–27) proceeded smoothly. After completing his second year with distinction in physics, chemistry and mathematics, Chandra's next step was to work toward a bachelor's degree.He wanted to take mathematics honours; he had excelled in mathematics and he had long been under the spell of the legendary Srinivasa Ramanujan. He was not quite ten years old when his mother told him of the death of a famous Indian mathematician named Ramanujan. Ramanujan had returned from England after collaborating with some famous English mathematicians, and returned to India only recently with international fame.

Unfortunately, Chandra's father had different ideas. He wanted Chandra to aim for the Indian Civil Service (ICS) examination to become an ICS officer in His Majesty's Government. By common consent that was certainly the practical thing for such a brilliant young man to do. From his high school days, however, Chandra had determined to pursue a career in pure science. There was the example of his uncle Sir C V Raman who had resigned a high-level government post to pursue an academic and research career in physics. Although Chandra wanted to study pure mathematics, as a compromise to his father, he opted to study physics and enrolled himself for a BSc honours degree.

The year 1928 became extraordinary for Chandra. First of all, in February and March of that year, Raman along with K S Krishnan made the fundamental discovery in the molecular scattering of light, later to become known as Raman Effect. Chandra spent the summer months in Calcutta, staying with Raman and working in the laboratory where the discovery was made. He knew enough theoretical physics to participate in the excitement and even explain to the experimentalists its significance. He came to know K S Krishnan very well. Although twelve years apart in age, the two struck up a friendship that lasted through Krishnan's lifetime.

Soon after his return to Madras, he learned from Krishnan that the famous German physicist and teacher Arnold Sommerfeld was to visit India on a lecture tour in the fall, and Madras and Presidency College were on his itinerary. For Chandra this was the most exciting news – a rare opportunity to hear the famous man, especially since he had read his

book *Atomic Structure and Spectral Lines* and worked through it on his own. He dreamed of meeting him, impressing him with his knowledge of atomic physics and discussing his plans for research. Indeed after the lecture in the science college, he made arrangements to see him in his hotel room the following day. Chandra approached him with the brash confidence of a young undergraduate but Sommerfeld shocked him by telling that the quantum theory in his book was outdated. He told him about recent discoveries – Schringer's wave mechanics and the new quantum mechanics of Heisenberg, Dirac, Pauli and others. Chandra had also studied classical Maxwell–Boltzmann Statistics. Sommerfeld told him that too had undergone a fundamental change in the light of the new quantum mechanics. Seeing a crestfallen young student before him, Sommerfeld offered him the galley proofs of his as yet unpublished paper that contained an account of the new Fermi–Dirac quantum statistics and its application to the electron theory of metals.

Chandra would later characterize this encounter as the *single most important event* in his life.

He immediately launched on a serious study of the new developments in atomic theory. Sommerfeld's paper was sufficient for him to learn about Fermi–Dirac Statistics and prepare, within a few months, a paper entitled *The Compton Scattering and the New Statistics.* Chandra thought it to be significant enough to merit publication in the *Proceedings of the Royal Society of London*. But the publications in the Society required the papers to be communicated by a Fellow member. Chandra, by chance, had come across Ralph Howard Fowler, a Fellow member, who had just published his pioneering paper on the theory of white dwarfs based on the new Fermi–Dirac statistics. So Chandra sent his paper to Fowler who agreed to 'communicate' it and got it published. This chance circumstance was to have a profound influence on Chandra's future scientific career.

Along with his studies, Chandra continued research on his own and by the end of his second undergraduate year he had a formidable list of papers to his name. Chandra's final year in college was equally eventful. First, Werner Heisenberg came to Madras on a lecture tour. Krishnan had put Chandra in charge to show Heisenberg around Madras. A day alone with the famous Heisenberg was an exhilarating experience for young Chandra. In addition, his activities and his prominence in studies and research had attracted the attention of Lalitha Doraiswamy, a fellow undergraduate who was to become his future wife. A few months later, in January 1930, he attended the Indian Science Congress Association meeting in Allahabad. He met the celebrated Meghnad Saha and his students and was pleasantly surprised to know his work had become well-known. He had the honor of being a dinner guest among the company of some distinguished senior Indian scientists. To top it all, on his return, he was called into the office of the principal of the college. Principal Fyson told Chandra, in strict confidence, that he was going to be offered a Government of India scholarship to continue his studies in England. The scholarship was special, more or less created for him. On 22 May, he received official notification that he had been awarded the scholarship and he could proceed to make the necessary travel arrangements. Chandra decided to go to Cambridge and study under the guidance of Fowler.

The opportunity to go abroad for advanced studies, ordinarily so difficult both financially or otherwise, came to Chandra so unexpectedly and so easily. Even so, he had to face a difficult personal conflict. His mother had been ill since the summer of 1928, just before his encounter with Sommerfeld. Her illness had taken a serious turn. After two years of every kind of treatment, although she had ups and downs, it had become clear she was not going

to become well again. If he went to England, he might never see her again. Tradition and pressure from friends and relatives mounted against leaving his mother in such a condition and go abroad. But Sitalakhsmi herself intervened. Her insistence and persuasion, her solemn desire not to stand in the way of his future, prevailed. With her promise of getting well, she persuaded the reluctant Chandra to proceed ahead. Chandra left India on 31 July 1930 leaving behind a loving and caring family, and Lalitha Doraiswamy.

5. Long voyage to England: Startling discovery

Before leaving Madras, once he had decided to work under Fowler for his further studies in Cambridge, Chandra studied Fowler's original paper more carefully and developed the theory of white dwarfs further to obtain a more detailed picture of the white dwarf star. On his long voyage from India, as a result of musings and calculations, Chandra found Fowler's theory needed modifications to include special relativistic effects and found it led to a startling conclusion:

There was an upper limit on the mass of a star that could become a white dwarf in its terminal stage. This upper limit could be calculated in terms of fundamental atomic constants.

When Chandra met Fowler for the first time, he handed over two papers, one he had completed in India and the other about the startling discovery he had made on his journey. Fowler was extremely pleased with this young, new student who exhibited so much independence and initiative. Fowler was quite pleased with the first paper that had extended his own work. However, he was not so sure of the second paper. He offered to send it to Edward Arthur Milne, who Fowler thought was more familiar with the subject. After getting no response from Fowler or Milne for months and seeing no possibility of its publication in *Mon. Not. R. Astron. Soc.,* Chandra sent it to the *Astrophys. J.* in America on 12 November 1930, where it was published (S Chandrasekhar, *Astrophys. J.* **74**, 81 (1931)).

6. Cambridge, England (1930–32)

Chandra's first year in Cambridge was mostly studies, attending courses in physics and pure mathematics. Among the lectures he attended during his first year were Dirac's lectures on quantum mechanics. Although Chandra had studied Dirac's book on his own, he attended his lectures faithfully, even though Dirac essentially copied onto the blackboard from his book. Dirac became his official advisor during the second term when Fowler left Cambridge on sabbatical and Chandra came to know him quite well. "He was very human, extremely cordial to me in a personal way," Chandra recalled. "Even though he was not very much interested in what I was doing, he used to have me for tea in his rooms in St. John's. He also came to my rooms for tea and, some Sundays, used to drive me out to fields outside Cambridge where we used to go for long walks."

Chandra continued to do research on relativistic ionization and on stellar atmospheres and began a correspondence with Milne. Milne was quite receptive of his work (but not of his startling discovery) and Milne's encouragement as well as his critical comments

were of great help to Chandra during those early days. Within six months, they had established a strong rapport and Milne suggested collaboration and joint publications. Chandra's research efforts were recognized – he was elected to Trinity College's 'Sheep Shanks Exhibition,' a special honour bestowed every year to one candidate for proficiency in astrophysics. It also carried an award of forty pounds. He received a congratulatory note from Arthur Stanley Eddington with an invitation to meet him on 23 May 1931.

However, on 21 May 1931, he received a devastating telegram:

Mother passed away Thursday 2PM Bear patiently

Chandra used to write letters home twice a week to his father and at least once a month to his younger brother Balakrishnan, and also to his mother in Tamil. His mother's health was constantly on his mind. In every letter he inquired about her health. As her health went through rapid ups and downs, he always hoped that she would get better. But that was not to be the case. Alone, with no one to share his grief, he went to the riverbank, sat and wept. Bear patiently, he told himself. He kept his appointment with Eddington two days after receiving the news, received congratulations and discussed his work, all the while feeling empty inside.

Work was the only panacea for loneliness and grief. He was working on stellar coefficients of absorption with Milne and had plans to spend the summer in Oxford. But after the news of his mother's death, he felt the need for a change from the drudgery of Cambridge and the past 11 months of ceaseless study and research. He thought a few months of diversion would provide the necessary relief. He spent the summer at the Institut Theoretische Physik at Göttingen where Max Born was working. Although the summer in Germany was supposed to be a vacation for Chandra, it became mostly a change of place and a change of study topics. But it helped to broaden his circle of friends in the continent. Chandra returned to Cambridge in early September to begin his second academic year.

7. Copenhgaen 1933

As Chandra continued his research and piled up publications, some in collaboration with Milne, a conflict slowly brewed in his mind. He was in astrophysics by sheer chance, because, on his own, he had found a problem to work on. He began to have nagging doubts about the value of the work in astrophysics he was doing. He was not receiving any encouragement in Cambridge. What about his true love – pure mathematics? He had come into physics due to the insistence of his father. Failing to pursue pure mathematics, he felt, he would have been happier if he could have devoted himself to pure physics, which he saw was the frontier field in which fundamental discoveries were taking place. The star studded Cavendish Laboratory was the centre of activity.

Dirac was his mentor, but because of a feeling of loyalty to Fowler, he hesitated to tell Dirac he wanted to switch fields from astrophysics to theoretical physics. But towards the end of his second year, he revealed to Dirac how unhappy he was in Cambridge and with what he was doing. Dirac, not being in astrophysics, was in no position to convince him otherwise. But he was very nice and understanding, and sympathized with Chandra's situation. He strongly urged Chandra to go to the Niels Bohr Institute in Copenhagen,

where he would find a better climate with friendly younger men, even though they were 'big men' in physics.

Chandra took Dirac's suggestion and spent his final year in Copenhagen. The atmosphere in Bohr's Institute was indeed, as Dirac indicated, quite unlike Cambridge. It was extremely friendly and truly international. Chandra found himself in a group of enthusiastic young people, including among others, Max Delbrück, George Placzec, Victor Weisskopf, E J Williams and Leon Rosenfeld. Chandra was particularly drawn to Leon Rosenfeld from Belgium, whose fiance was studying astrophysics. There were also frequent visitors like Oscar Klein and Heisenberg. With new friendships, tea every Sunday at Bohr's house, walks and bicycle riding in the country, Chandra's life took on a new social dimension.

He was also happy that he was working on a problem in physics that Dirac had suggested: generalizing Fermi–Dirac statistics to more than two particles. Unfortunately that did not work out. He believed he had solved the problem and with the approval of Bohr and Rosenfeld sent the paper for publication in the *Proceedings of the Royal Society*. But Dirac found an error and convinced Chandra that he had not solved the problem. The paper had to be withdrawn and with that his attempt of switching fields from astrophysics to pure physics had to be abandoned, at least for then. Physics was the fundamental science, so while he socialized with physicists like Weisskopf, Delbruck, Kopferman, and others who appeared to be at the hub of important discoveries, he was not part of their science. As December came along, it became clear that he had to get his thesis ready to get his degree before the end of his scholarship in August 1933. Back to astrophysics, he set himself to prepare a series of papers in distorted polytropes for his thesis.

8. A Fellow of Trinity College: An unexpected encounter

The degree became just a formality. Fowler did not find it necessary even to read it. However, Chandra felt his future to be bleak. His scholarship would end at the end of August and he was required to return to India as soon as he completed his Ph.D. degree. He was under pressure from his father as well to return, but there was no promise of a suitable position that would allow him to continue his research and studies. He was determined to extend his stay in Europe. He would seek support from Cambridge and Copenhagen. If nothing materialized, he had sufficient savings for an extended stay for at least six months anywhere in Europe. With little hope, he applied for a Fellowship of Trinity College, a wild dream. If it came true, he would have four more years in Cambridge with free rooms in the college, dining privileges at the high table, and an allowance of 300 pounds per year.

The dream did come true. The only other Indian who had been elected to a Trinity Fellowship was Ramanujan some sixteen years before. Chandra's Cambridge life changed to a more enjoyable surroundings. He was no longer as lonely as before. He felt assured of his work being appreciated. Astrophysics was going to be his predominant area of research, at least for the next four years. As a Trinity Fellow, he could become a Fellow of the Royal Astronomical Society on his own merit and did so without much ado. A trip to London to attend these meetings every second Friday of the month became a routine in his life and allowed him to make a mark on the tradition-ridden, hierarchical scientific surroundings characteristic of the English. The Fellowship also brought an opportunity to visit Russia during the summer of 1934.

The Russian visit also renewed his interest in his own earlier work on the theory of white dwarfs. Neither Fowler nor Milne appreciated the startling discovery he had made. During the intervening years, 1932–1934, he had occupied himself with other problems. When in Copenhagen, however, at the encouragement of Leon Rosenfeld, he published a longer paper (*Z. Astrophys.* **5**, 321 (1932)), in which he wrote the often quoted statement,

"For all stars of mass greater than M [1.2 times the critical mass], the perfect gas equation of state does not break down, however high the density may become and the matter does not become degenerate. An appeal to Fermi–Dirac statistics to avoid the central singularity cannot be made,"...

He continued,

"Great progress in the analysis of stellar structure is not possible before we can answer the following question: Given an enclosure containing electrons and atomic nuclei, what happens if we go on compressing the material indefinitely."

In Russia, he gave talks about this work and Victor A Ambartsumian, in particular, was quite enthusiastic about his discovery. He suggested he should work out the exact, complete theory devoid of some simplifying assumptions he had made. During the fall of 1934, he involved himself in detailed, tedious, numerical calculations to obtain as an exact theory of the white dwarf as one could construct within the framework of relativistic quantum statistics and the known features of stellar interiors. He accomplished this task by the end of 1934 and submitted two papers to the RAS. At their invitation, he presented a brief account of his results at the January meeting of 1935. His findings raised challenging and fundamental questions: what happens to the more massive stars as they continue to collapse? Are there other terminal stages different from those of white dwarfs? Instead of getting appreciation and recognition for a fundamental discovery, Chandra unexpectedly faced what amounted to a public humiliation. Because, no sooner had he presented his paper than Sir Arthur Eddington, who had been his mentor and who had followed his work closely, ridiculed the basic idea of 'Relativistic Degeneracy' on which Chandra's work was based. He characterized the theory as amounting to *reductio ad absurdum* behaviour of the star, tantamount to stellar buffoonery (for details see, for instance, K C Wali, *Chandra: A biography of S Chandrasekhar*, University of Chicago Press, Chicago, p. 124).

Eddington's cavalier dismissal of his work was a traumatic experience for young Chandra, who was pitted against an imposing scientific luminary. Chandra sought the support of eminent physicists (Rosenfeld, Bohr, Dirac, Pauli), who without exception agreed that his derivations were flawless, but were reluctant to come out openly and say Eddington was wrong. Astrophysics was simply not part of the mainstream, frontier physics. Important discoveries were taking place in fundamental physics. Eddington's authority prevailed among the astronomers as he continued to attack the theory.

In the face of such opposition, Chandra made a wise decision to gracefully withdraw from the controversy instead of engaging in a dogged fight. He stopped further work on the theory of white dwarfs and went on to research in other areas. As he said (*Chandra: A biography of S Chandrasekhar*, p. 146):

"I foresaw for myself some thirty years of scientific work, and I simply did not think it was productive to harp on something which was done. It was much better for me to change

the field of interest and go into something else. If I was right, then it would be known as right. For myself, I was positive that a fact of such clear significance for evolution of the stars would in time be established or disproved. I didn't see a need to stay there, so I just left."

9. Quest for perspective: A scientific autobiography

People did come to know Chandra was right in time. In retrospect, the traumatic event became a turning point in Chandra's life. It had a 'sobering effect': he became inward bound. He developed a distinctive style of research dominated by aesthetic considerations. The relentless mastery of a certain area and, once mastered, the ability to leave it entirely for another became Chandra's hallmark in his scientific pursuits.

In late 1980s, while I was working with Chandra on his biography, he mentioned a journal he kept of his scientific activities, and one day he handed me a copy of what he had at the time. It was supposed to be confidential, and after his death, if his wife Lalitha and I thought it of interest and worthwhile, he would like to see it published. Chandra led a life of supreme and almost unparalleled effort in unraveling the laws of nature encoded in mathematics. The journal gave a rare and personal insight into the joys and struggles of a brilliant scientist at work. The year 2010 marked Chandra's birth centennial and seemed the perfect time to bring to light this unique document, *A Scientific Autobiography*: *S Chandrasekhar*, edited by Kameshwar C Wali (World Scientific, 2011) (figure 3).

As Chandra says in the preface:

"The various instalments describe in detail the evolution of my scientific work during the past forty years and records each investigation, describing the doubts and the successes, the trials and tribulations, and the parts my various associates played in the completion of the different investigations are detailed."

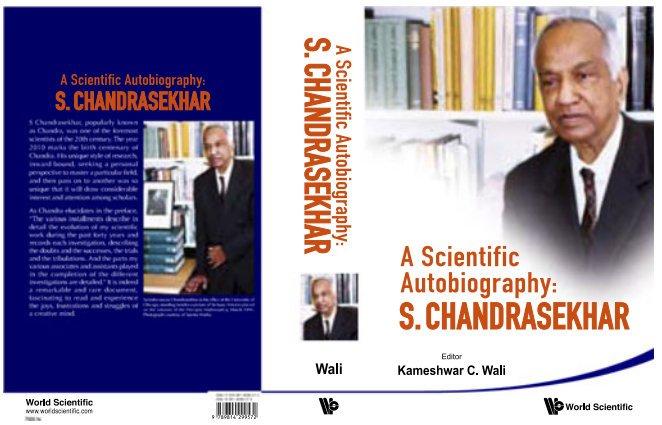

Figure 3. A Scientific Autobiography.

And towards the end of the preface:

"Lalitha only rarely mentioned, was always present, always supportive, and always encouraging, and this is the place to record the depth of my indebtedness to her. But the full measure of it cannot really be recorded: It is too deep and all persuasive. Let me then record very simply that Lalitha has been the principal motive force and strength in my life. Her support has been constant, unwavering, and sustained... and so, I dedicate this autobiography, which is indeed my life, to her (figure 4)."

The book begins with his work on *Radiative Transfer,* about which he says:

"My research on radiative transfer gave me the most satisfaction. I worked on it for five years, and the subject, I felt, developed on its own initiative and momentum. Problems arose one by one, each more complex and difficult than the previous one, and they were solved. The whole subject attained elegance and a beauty which I do not find to the same degree in any of my other work. And when I finally wrote the book, *Radiative Transfer*, I left the area entirely. Although I could think of several problems, I did not want to spoil the coherence and beauty of the subject [with further additions]. Furthermore, as the subject had developed, I also had developed. It gave me for the first time a degree of self-assurance and confidence in my scientific work because here was a situation where I was not looking for problems. The subject, not easy by any standards, seemed to evolve on its own."

It is this kind of insight that illuminates the contextual circumstances surrounding his body of work and gives it a depth of purpose we could not know otherwise. Happy or otherwise, a unique style of research was to continue for the rest of his life. As revealed in this scientific autobiography, and as Chandra himself noted in the autobiographical account published with his Nobel Lecture:

"After the early preparatory years, my scientific work has followed a certain pattern motivated, principally, by a quest after perspectives. In practice, this quest has consisted in my choosing (after some trials and tribulations) a certain area which appears amenable to cultivation and compatible with my taste, ability, and temperament. And when after some

Figure 4. Lalitha Chandrasekhar (1997).

years of study, I feel that I have accumulated a sufficient body of knowledge and achieved a view of my own, I have the urge to present my point of view ab initio, in a coherent account with order, form, and structure."

This autobiography is a testimony to his having carried out his quest to its perfection. The inner workings described in this document go beyond the vast landscape of physics, astrophysics and applied mathematics. Chandra's published papers and monographs evoke a feeling of respect and wonder. While to a casual student it may seem intimidating and forbidding, for the serious-minded, however, they leave an indelible impression of their endearing value in spite of the continual progress in the respective fields. They convince one of the innate values of science – the continuity, the interdependence, and the necessity of combining original research with scholarship. Likewise, this autobiographical journal reveals Chandra's human side, the man behind the legend – his intense association with his students and associates and his ability to inspire in others hard work and enthusiasm. As we read we find, with perspective gained in one area to his satisfaction, he leaves the area entirely and proceeds to another with a complete sense of detachment, ready to start fresh in a new area (figure 5). If necessary, he attends classes, take notes, and studies as if he were once again a student. Or he will teach a course, and may be give a series of lectures on the subject he wants to learn. He might, on the drop of a hat, fly to Huston, Texas or Oxford, England to have a discussion with Roger Penrose, or to Crete and Rome to work with his young collaborators, Basilis Xanthopoulos and Valeria Ferrari.

Chandra's intensity and fervor for completeness, elegance, and above everything else, gaining a personal perspective extended beyond his scientific publications to his semi-popular lectures and essays. As an example of the amount of effort he would put in, I choose his famous Ryerson Lecture (1975), *Shakespeare, Newton, and Beethoven, or Pattern of Creativity*. I quote from this autobiography,

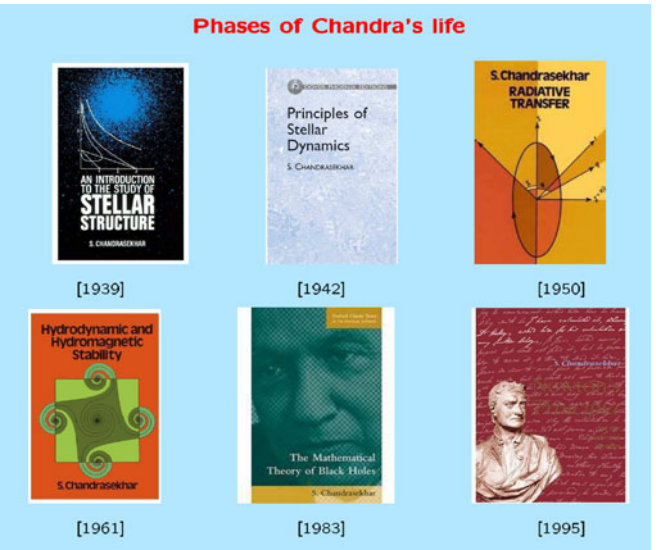

Figure 5. Six phases of S Chandrasekhar (courtesy of Professor T Padmanabhan).

"The months of January, March, and most of April were devoted entirely to preparing my Ryerson lecture, indeed, a larger part of the preceding months (including the weeks in the hospital in Sepember) were spent towards that end. The preparation consisted in reading several biographies of Shakespeare, his sonnets in Rowses Edtions very carefully, and listening with text to all the great tragedies (in their Marlowe editions); reading several biographies of Beethoven (particularly Turner's and Sullivan's); and similarly reading several biographies of Newton; besides the lives of Rutherford, Faraday, Michelson, Mosley, Maxwell, Einstein, Rayleigh, Abel; and books and essays by Hadamard, Poincare and Hardy; and the works of Keats and Shelly, and most particularly Shelly's, A Defence of Poetry and King-Hele's biography of Shelly."

In the article *The Series Paintings of Claude Monet and the Landscape of General Relativity*, Chandra speaks about the similarity of Claude Monet's motivations in paintings his 'Series Paintings' and his motivations in the series of papers on black holes, colliding waves and scattering of gravitational radiation. In Monet's painting the same scene is depicted over and over again under different natural illumination and seasonal variations. The valley, the trees and the fields, and the hay stacks are the same. However, the different paintings radiate totally different aesthetic content. Only seen as a group, a viewer can obtain a deeply convincing sense of the continuous nature of experience in contrast to the shifting nature of what one observes. In a similar fashion, the same set of static symbols, which form the landscape of general relativity, manifest in different roles in equations, unifying the description of vastly different physical phenomena, making the general relativity as sometimes described as one of the most 'Beautiful' theory.

At the end of that essay, Chandra says he does not know if there has been any scientist who could have said what Monet said on one occasion,

"I would like to paint the way a bird sings."

But we do know a scientist who spoke like a poet,

"The pursuit of science has often been compared to the scaling of mountains high and not so high. But who amongst us can hope, even in imagination, to scale the Everest and reach its summit when the sky is blue and the air is still, and in the stillness of the air survey the entire Himalayan range in the dazzling white of the snow stretching to infinity? None of us can hope for a comparable vision of Nature and the universe around us, but there is nothing mean or lowly in standing in the valley below and waiting for the sun to rise over Kanchanjunga."

10. In conclusion

With such writings, often filled with parables, quotes from modern and ancient literature, Chandra bridged the gap between what C P Snow called Two Cultures – the culture of the sciences and of the humanities. While there have been many scientists whose discoveries had perhaps greater impact and whose names have become more illustrious, in my opinion, Chandra stands alone for his single-minded pursuit of his science and his devotion to the

life of the mind. The years I worked with him, writing his biography, were some of the most enjoyable and creative years of my life.

Chandra often quoted from a letter of his friend Edward A Milne during his Cambridge years:

"Posterity, in time will give us our true measure and assign to each of us our due measure and humble place; and in the end it is the judgement of posterity that really matters. He really succeeds who preserves accordingly to his lights, unaffected by fortune, good or bad. And it is well to remember there is no correlation between posterity and the judgement of contemporaries."

This first centennial celebration of Chandra's birth may or may not be the moment to determine his true measure of posterity. However, it marks the beginning of that posterity's judgement to bestow on him his due place as a scientist of rare stature and greatness.