Subramanya Chandrasekhar: A Star was Born

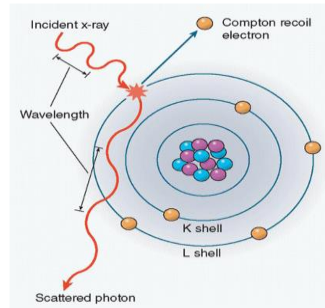
Humans have long been curious about the mysteries of nature and paradoxes. This need for knowledge has fuelled human growth and advancement throughout history. While not everyone has pursued this line of investigation, some have ventured to question the conventional viewpoints and ask the "Right Questions". These are individuals who were known as "Philosophers" in antiquity are called as "Scientists" today. One such scientist was Arthur Eddington, who raised an eyebrow to one of history's finest scientists: "What happens when a star dies?" The answer to this question won the latter scientist a Nobel Prize for his pioneering work in astronomy. He was none other than Indian American Astrophysicist Subrahmanyan Chandrasekhar, who discovered the Chandrasekhar limit and developed the theory of star evolution. In this blog, we'll look at his life, challenges, and legacy.

Early Life and Schooling

Subramanyan Chandrasekhar was born on October 19, 1910, in Lahore, Punjab, India (now part of Pakistan). He was the third child of Sita Balakrishnan and Chandrashekara Subrahmanya Iyer, a civil servant and a scholar. His paternal uncle was the famous physicist C.V. Raman, who would later win the Nobel Prize in Physics for his discovery of the Raman effect. Chandrasekhar’s family moved several times during his childhood, first to Allahabad in 1916, where his father worked as the Deputy Accountant General, and then to Madras in 1918, where he settled as the Deputy Auditor General. He received his early education at home, where his father taught him mathematics and physics, and his mother taught him Tamil. He showed a remarkable aptitude for science and mathematics from a young age and was fascinated by the works of Newton, Maxwell, and Einstein. In 1922, he enrolled in the Hindu High School in Madras, where he excelled in his studies and won several prizes. In 1925, he entered the Presidency College in Madras, where he obtained his B.S. Honors in Physics in 1930, with the highest marks ever recorded in the college.

His First Work

Inspired by German Theoretical Physicist Arnold Sommerfield, who was considered one of the pioneers for the foundations of Atomic and Quantum Physics, Chandrashekar published his first paper "The Compton Scattering and the New Statistics" during his Bachelor's Degree. In his first paper, he discussed the behaviour of the free electrons in the metals.



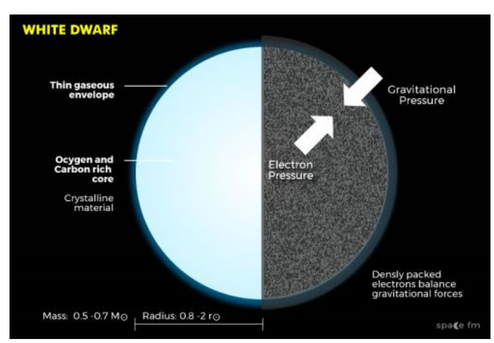
Before this paper, the famous physical phenomenon called "Compton Scattering or Compton Effect" which states that when a Photon interacts with a Free electron, as they collide Photon kicks out the outermost shell electron from the atom and transfers some of its energy to the electron, thus Photon loses its energy and its wavelength is increased. The Normal assumption in this effect was that the free electrons were stationary when photons struck them.

But Chandrashekar in his paper, suggested a more realistic way to describe the Compton Scattering, he assumed that the Free Electrons are not stationary but rather moving when Photon strikes them. This approach to studying Compton Scattering was more accurate than the previous ones. This approach even strongly supported the Fermi Dirac Statistics which was newly developing at that time. This was a significant addition to the study of physics, and it is regarded as one of the key works to learn about quantum mechanics and electron behaviour.

This work was written during his undergraduate studies. And for this paper, he obtained a scholarship from the Government of British India to continue his graduate studies at the University of Cambridge, Trinity College. His study was well regarded by most reputable scientists of the period, including R H Fowler, a Physicist and Astronomer at the same college. This is when Chandrashekar acquired a strong interest in astronomy, which led to his success as a prominent Indian physicist.

Higher Education and Career

As a research student under R H Fowler at Cambridge University, he started his work on the limiting mass of the stars, a problem that had puzzled astronomers for decades. He received an invitation from Max Born, one of the pioneers of quantum mechanics, to continue his postgraduate studies at Born's Institute in Gottingen, Germany. There, he worked on stellar photospheres, the outer layers of stars that emit light. In his final year, he went to the Institute of Theoretical Physics in Copenhagen, where he worked with Niels Bohr, the father of atomic physics. In his graduate thesis, he mainly worked on improving the stellar evolution models, which describe how stars change over time. He proposed the theory of the limiting mass of white dwarfs, which are the remnants of low-mass stars that have exhausted their nuclear fuel. He stated that the white dwarfs are supported by the pressure of the degenerate electrons, which obey the quantum mechanical rules of statistics. He showed that there is a maximum mass for a white dwarf, beyond which it cannot be stable and would collapse into a denser object. This mass limit, now known as the Chandrasekhar limit, is about 1.4 times the mass of the sun.



He was rewarded with a PhD from the University of Cambridge for his work on the Self Gravitating Polytropes. He received a Prize Fellowship from Trinity College from the year 1933 to 1937. He became the second Indian to receive the Trinity Fellowship after Srinivas Ramanujan who had received it 16 years earlier.

Impressed by his work in the field of Astrophysics, Chandrashekar was invited by the director of the Harvard Observatory to be a Visiting Professor in theoretical Astrophysics. This is when he travelled to the United States. Impressed by his teaching skills, Chandrashekar was offered a Harvard Research

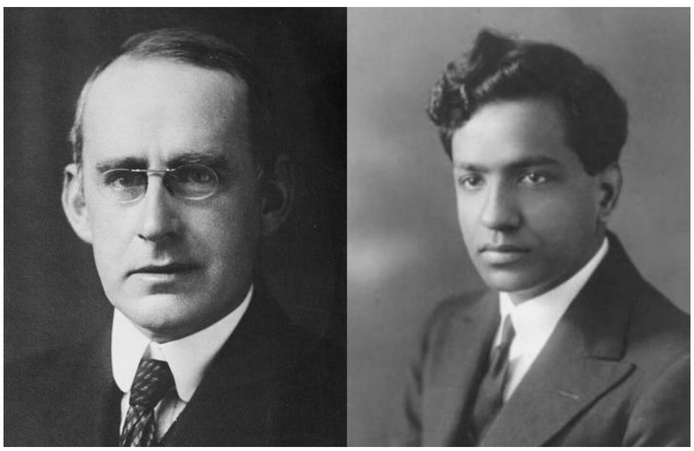
Fellowship but he declined it as Chandrashekar during his stay in the US was impressed by the work of Gerard Kuiper who had worked on White Dwarfs. He decided to join the Yerkes Observatory in Wisconsin, which was under the University of Chicago. Thus, he joined the University of Chicago as an assistant professor and he stayed in the University of Chicago throughout his career. He was even offered a double salary from Princeton University to join them but the University of Chicago doubled the amount to make Chandrashekar Stay at University of Chicago. The Image in the right was taken when he was in the University of Chicago.

Defending his thesis (Scientific Discussion, ignore it if not interested)

This paper of his was game-changing as it changed the entire perspective of the stellar evolution. He suggested that once the low-mass stars undergo novae explosion after the Red Giant Phase, they form White Dwarfs whose mass can never exceed 1.4 times the mass of the sun. This limit is called as “Chandrashekar Limit”. This was a major discovery as scientists really didn’t understand anything much about the stars after their death. He explained the stability of the white dwarfs using the famous Pauli’s Exclusion Principle, where he said that, the White Dwarfs are in the state of Plasma which tells us that the particles present in the stars are not in the form of Atoms but in the free state like Electrons and Nuclei, he said white dwarfs are stable because as the Pauli’s Exclusion principle suggests that two electrons cannot occupy the same energy level unless they have opposite spin and Since, electrons are fermions they follow Fermi Dirac Stats. Based on Fermi Dirac Stats all the electrons cannot occupy the lowest energy level but have to go higher and higher energy levels as the lower ones get filled. This filling up of electrons causes electrons to travel to higher energy levels which creates something called as “Degenerate State” of Electrons. As a result of the Degenerate State of Electrons, the electrons start to move outwards to fill up the higher energy level. Remember all the electrons try to occupy the lower energy level to remain stable, so to occupy the lower energy levels which will be made available as soon the one lower than it fills up, the electrons move rapidly towards it. Thus, the electron moves at a high velocity. Upon that Gravity squeezes the white dwarf inwards (not just white dwarf every celestial body experience this), thus decrease in the space within the white dwarf results in the reduction of the space for electrons to move around. According to Heisenberg’s Uncertainty Principle, the position and Momentum of the electron could not be determined at the same time. The equation of the Uncertainty Principle suggests that the momentum of an electron is inversely proportional to its position (not really, just telling this so that the concept could be understood better) Since the position of the electron (the space available for the electron to move around) is reduced the momentum of electron increases. Since the momentum is a product of the velocity and mass of the object (p = mv), it shows that momentum is directly proportional to the velocity thus velocity of the electron is also increased. Thus, the electrons moving outwards (to higher energy levels) will exert high outward pressure due to high velocity against the gravitational pressure acting inwards. This high outward pressure caused by the electrons is called as the electron degeneracy pressure. Thus, Chandrashekar was able to explain the stability of the White Dwarfs.

The Famous Chandrashekhar – Eddington Dispute

The history of astrophysics is full of fascinating stories of discoveries and debates, but perhaps none more so than the Eddington-Chandrasekhar controversy. It was a clash of titans between two of the greatest theoretical astrophysicists of all time: Arthur Eddington, who was famous for his experimental verification of Einstein's general theory of relativity, and Subrahmanyan Chandrasekhar, a young Indian prodigy who made a breakthrough in the study of stellar evolution.

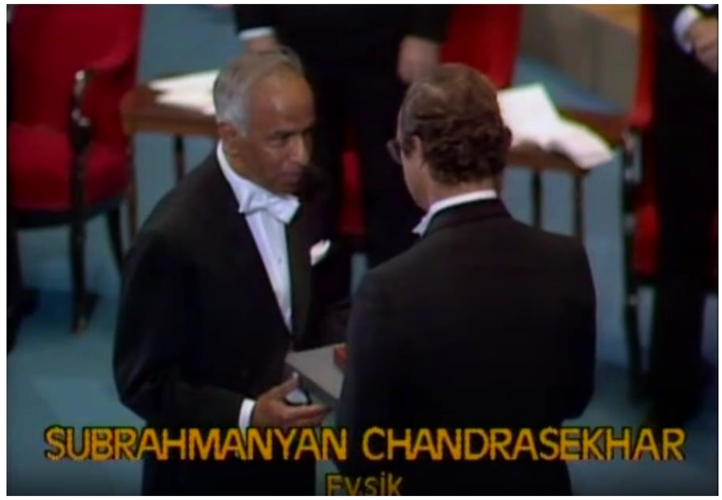


The controversy revolved around the fate of white dwarfs, which are the remnants of low-mass stars that have exhausted their nuclear fuel. Chandrasekhar showed that there is a maximum mass for a white dwarf, known as the Chandrasekhar limit, beyond which it cannot be stable and would collapse into a denser object. Eddington, who was Chandrasekhar's PhD examiner, refused to accept this idea and argued that all stars would end up as white dwarfs.

He publicly criticized Chandrasekhar's work in several conferences, causing him much distress and disappointment. However, Chandrasekhar persisted in his research and gained support from other eminent physicists such as Pauli, Dirac, Bohr, and Rosenfeld, and in the year 1941, Dirac proved Eddington's arguments on Chandrasekhar's theories were wrong. Eddington died in 1944, without ever acknowledging Chandrasekhar's theory.

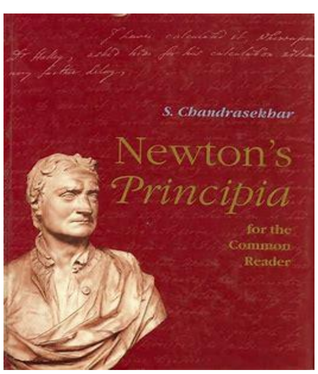
Dinner of the Royal Astronomical Society Club, 12 June 1936. Chandrasekhar (seated third from the left) attended as a guest of Eddington (second from left). W. M. Smart, then secretary of the Royal Astronomical Society, and later the Regius professor of astronomy at Glasgow, Scotland, is on Chandrasekhar's left. (Photograph courtesy of S. Chandrasekhar.)

In 1972, the discovery of Cygnus X-1, the first black hole ever detected, vindicated Chandrasekhar's prediction that not all stars become white dwarfs after their death. In 1983, Chandrasekhar and William A Fowler shared the Nobel Prize for their work on the understanding of the physical processes of star structure and stellar evolution.



World War 2 & His Legacy

Subrahmanyan Chandrasekhar was also a versatile and visionary scientist who worked on various topics such as ballistics, hydrodynamics, relativity, and mathematical physics. During his stay in the USA, he worked in many different laboratories and when he was working in the Ballistics Research Laboratory, he published his work on the problems of ballistics. Impressed by his work on atomic physics, He was invited by Robert Oppenheimer to join the Manhattan Project, but he could not participate due to security clearance issues. He died of a heart attack in 1995, after surviving one in 1975. He was honoured by NASA for his contributions to astrophysics by naming one of its greatest observatories as Chandra, which was launched in 1999.



He continued to work on the field of astronomy even in his 80s, and wrote the book "Newton's Principia for the Common Reader", where he explained Newton's laws of motion using ordinary calculus. He also worked on the collision of gravitational waves and the mathematics behind them in his 70s, and his work is still followed by many scientists today. He was recognized by the Association of Asia Pacific Physical Societies (AAPS) with the Chandrasekhar Prize of Plasma Physics, which is awarded to outstanding plasma physicists. Chandrasekhar was a remarkable scientist who left a lasting legacy in the world of science.