

K. SMILES MASCARENHAS

Sir C. V. Raman

Icon of Indian Science

7th November 2013 marks the 125th birth anniversary of the legendary Indian scientist and Nobel Laureate Sir Chandrasekhara Venkata Raman. This article is a tribute to the great man, who from a humble beginning rose up to be one of the greatest physicists the world has ever seen.

(In developing the article I have drawn heavily from the lectures on Raman given by my mentor and friend Dr. S. Ramaseshan (a noted crystallographer and the nephew of the great man). Ramaseshan was also a student of Raman and he had ample opportunity to observe the Nobel laureate at close quarters.)

RAMAN was born in Thiruvanaikaval, near Tiruchirappalli, Madras Province, Chennai, in British India to R. Chandrasekhara Iyer and Parvati Ammal (Saptarshi Parvati). They had eight children – five sons and three daughters.

As Ramaseshan mischievously remarks: it is obvious that Chandrasekhara Iyer did not believe in family planning. Had he stuck to the statutory limit of two children, Raman would have still made it (being the second son). But he (Ramaseshan) would not have been in

a position to give a talk about Raman (he was the son of Raman's little sister Sitalakshmi!).

When Raman was three, his father accepted the post of a lecturer in mathematics and physics in Mrs. A.V.N. College, Vizagapattinam in Andhra Pradesh. Raman studied at the Aloysius Anglo-Indian High School and proved to be exceedingly brilliant in his studies. At a rather young age of eleven, Raman passed his matriculation exam, and went on to complete his FA at the age of thirteen.

His father then moved to Chennai as a lecturer in mathematics and physics at Presidency College in Madras, which Raman entered in 1902 at the age of 13. In 1904 he passed his B.A. examination in first place and won the gold medal in physics, and in 1907, at the age of 18, he gained his M.A. degree with the highest

distinctions. It is said that many of his science professors exempted him from attending science classes, as they felt he had nothing to learn from them. Would the ego of modern teachers allow them to do a similar thing with their students, in this era?

It is widely believed that Raman's chief claim of fame rests on his discovery of the Raman effect (just because he won the 1930 Physics Nobel prize for its discovery). But Raman made many seminal contributions to physics and in many diverse areas on science that led to our understanding of nature.

At the age of 16, while measuring the angle of deviation of refracted light through a prism, Raman observed some diffraction bands. He did not overlook the bands and seriously investigated them further. This investigation formed

Unlike most traditional Indians of his day, he never believed in superstitions and despised rituals. He never forced his sons to observe any of the traditional customs that were strictly followed by his family.

the subject of the first paper he published in the *Philosophical* magazine (London) in 1906. On reading this article many eminent scientists in London noted the talent of this young Indian. This was followed by a note in the same journal on a new experimental method of measuring the surface tension. All these publications were communicated by the author himself and it contained no acknowledgement of any help he received from his professors.

When he passed his B.A. examination, his teachers recommended that he should go to England for his higher studies. But the Civil Surgeon in Madras found him to be weak in stature and declared that the harsh English climate would kill him. He was thus medically disqualified from seeking higher education in England. Later, Raman remarked about the civil surgeon adding that he shall be ever grateful to him.

In 1906, after his M.A., Raman wanted to compete for the I.C.S. examination. But to write that examination, one had to go to London. As he was poor and could not afford it, he took the Indian Financial Service examination, conducted in India. He passed the exam, topping the list of selected candidates.

Against all conventions of the time, he arranged his own marriage with Lokasundari who was then 13 years old. Whether the marriage was conducted with the traditional pomp and religious manner or in a very simple manner is not clear. Later Raman categorically stated that he was an agnostic, and if this conviction prevailed when he was young, it is quite possible that Raman would not have gone for a traditional religious marriage. Lokasundari later declared that she did not know if Raman married her for the extra allowance which the Finance Department gave to its married officers!

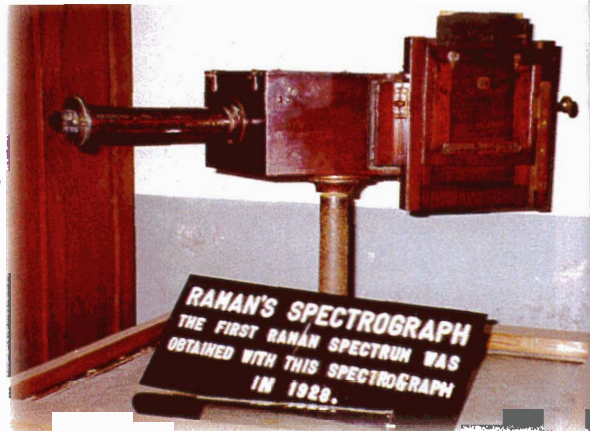
In 1907, the young couple moved to Calcutta, where he became the Assistant Accountant General at the Finance department. They rented a house in Scots lane, off Bowbazar Street. While on his way back from work by tram, fate led him to take note of The Indian Association for the Cultivation of Science (IACS) at 210, Bowbazar Street. On a Sunday, he

paid a visit to the center and knocked at the door. It was opened by a simple looking man named Ashutosh Dey. Destiny led Raman to the person (fondly referred as Ashu Babu, by him) who was to be his faithful assistant for the next 25 years. What Raman saw must have initially disappointed him – a dusty hall and a large laboratory with dustier equipments found in college labs.

Ashu Babu introduced Raman to Sri Amrit Lal Sircar, the secretary of the Association. Raman came to know that the IACS was established in 1876 by Amrit Lal's father, Sri Mahendra Lal Sircar, a man of vision, who wanted to have an Institution where young scientists could carry out research. It started out well by hosting scientific lectures and seminars by men of science, but no research of any type was carried out. Mahendra Lal was critical about the apathy of Indians towards cultivation of science but hoped that someday younger men would step in and make the place a great Institution.

When Raman expressed his desire to use the lab for his research, Amrit Lal Sircar was convinced that Raman was the young man that his father had dreamt about and promptly handed over the keys of the lab to him. In three years Raman turned it into one of the most important centers of original research in the world!

Lokasundari must have despised Raman's revised schedule after discovering the Indian Association – early morning by 5:30 AM, Raman goes to the Association. Returns by 9:45 AM, bathes and gulps his food in haste and rushes to his office, invariably by taxi (Raman believed in being punctual to work). After work at 5:00 PM, he rushes directly to the Association only to return home late at night by 10:00 PM and have a late dinner. He could afford to hire a Brahmin cook, with the extra marriage allowance that he received. Otherwise Lokasundari would have had to prepare meals for him at odd hours. On Sundays and other holidays, he would spend the entire day at the Association – not an exciting life for the young bride.



Lokasundari found solace in visiting a beautiful church at the end of Scots lane. Slowly Raman was also attracted to the church, not because he was convinced of the divinity of Jesus Christ (remember, he was a confirmed agnostic?), but because he loved the rhythmic music of the reed Organ used by the choir. (His keen ears were silently doing a Fourier analysis of the Organ!)

The Brahmin cook they hired resented that they visited the church and showed his ire by resigning his job! He even passed the message on their "conversion to Christianity" to Raman's father, who promptly wrote a thundering letter to Raman. Considering that Raman was a man with great determination, I doubt if he would have heeded his father's advice!

For a short duration (in 1909), he was transferred to Rangoon, Burma (now called Myanmar) which was then a part of British India. After that in 1910 he was transferred to Nagpur and in 1911 he returned to his "home" in Calcutta. All these transfers did not deter his scientific investigations, since wherever he went, he converted his house into a mini laboratory! It is said that after his return to Calcutta, he took up residence next door to the IACS, and constructed a door that led directly into the institute, giving him access at any

Back at his favourite place, he and Ashu Babu are the only workers at the IACS. He starts the Bulletin of the Indian Association wherein he publishes many monographs. In 1917, the Bulletin becomes the Proceedings and much later, the *Indian Journal of Physics*. What were the things that he was investigating? Chiefly music – he enjoyed listening to the violin, the organ, sounds made by heated metals and any phenomenon that produced innumerable harmonics!

Ashu Babu was his only assistant and his name appears in many of their publications. Raman was very proud

when a paper was published in which Ashu Babu was the sole author! A great achievement for a man who never entered the portals of a college!

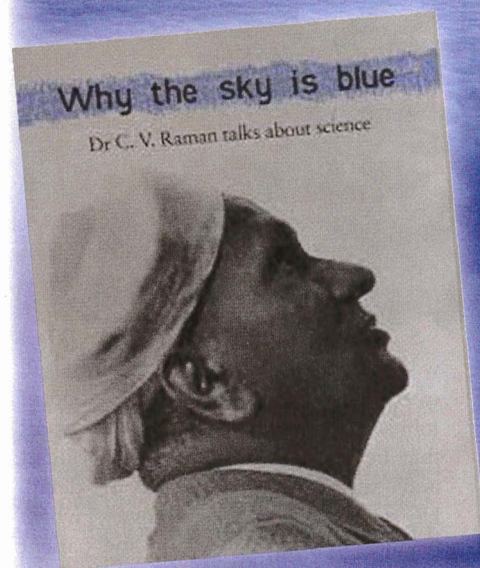
Raman was immensely successful as a Finance Officer as he was much appreciated by his superiors. At this point in time, Sri Ashutosh Mukherjee, the Vice-Chancellor of the Calcutta University, offered him the Palit Chair of Physics. Raman accepted the offer, even though the salary was much less than what he was getting. But one of the requirements of the Chair was to have a training abroad. Raman refused to go to England. However, under pressure from Sri Ashutosh, Raman made his first trip to London in 1921.

He was already well known in the scientific circles for the papers he published in optics and acoustics. The renowned English physicists J.J. Thomson and Lord Rutherford recognized him and gave him a warm reception. (For this recognition, Raman gave full credit to the turban he was wearing and not to his scientific accomplishments!) Raman's specialty had been the study of the vibrations and sounds of stringed instruments such as the violin, the Indian veena and tanpura, and two uniquely Indian percussion instruments, the tabla and the mridangam.

But it was the return trip from London to Bombay aboard the SS Narkunda that

turned out to be his inspiration. During the fifteen-day voyage, he became fascinated with the deep blue colour of the Mediterranean Sea. He was unable to accept Lord Rayleigh's explanation that the colour of the sea was just a reflection of the blue colour of the sky. He used his pocket polarizer (a simple Nicol prism) at Brewster angle to cut off reflections from the sky. Standing at the helm of the ship, with his cardboard tubes and optical gadgets, he must have been an odd spectacle to all his fellow passengers! Raman proceeded to outline his thoughts on the matter while still at sea and sent a letter to the editors of the journal *Nature* when the ship docked in Bombay.

On his arrival, he isolated the violet light of the solar spectrum with a filter and passed it through a liquid sample (ultra pure water!). Most of the light emerging from the liquid sample was the same colour as the incident violet beam: the so-called Rayleigh scattered light. However, Raman and his brilliant student K.S. Krishnan (fittingly, the magazine that you are holding right now is being published by an Institute located on "K.S. Krishnan Marg"!) were able to show that some of the scattered light was a different colour, which they could isolate by using a green filter placed between the observer and the sample. The advantage of using a visual observation is that several substances can be studied quickly.

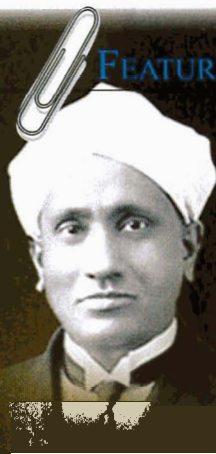


In his first report to *Nature*, titled "A New Type of Secondary Radiation", Raman indicated that approximately 60 different liquids had been studied, and all showed the same result—some scattered light had a different colour than the incident light. Raman declared: "This is a phenomenon whose universal nature has to be recognized."

The Raman Effect is a very weak effect; only one in a million of the scattered light particles (already called photons by this time), actually exhibits the change in wavelength. This explains, in part, why the effect was not discovered earlier. In all of the early light-scattering studies, the excitation source was sunlight, which Raman has described as being plentiful in Calcutta, but it still lacked the desired intensity.

The acquisition in 1927 by the IACS of a seven-inch (18 cm) refracting telescope enabled Raman to collect more sunlight and create a more powerful light source for his studies. Raman's dependence on the Sun as a source of light for his observation had some serious disadvantage (he made his own "heliostat" by attaching a mirror to an old alarm clock!). Sometimes, he and his associates "zeroed in" on an interesting observation, when the Sun decided to set. So, they were forced to spend a sleepless night till the Sun rose the next day! However, by early 1928, mercury arc lamps were commercially available, and he switched to this even more intense light source.





C V Raman (1888 - 1970)

Notable Indian Nobel Laureate for Physics, known for discovery of "Raman Effect"

(among all the Nobel Prizes awarded, this must have the shortest in duration from the time of discovery).

He was knighted by the British government in India and received the Nobel Prize in physics in 1930

The significance of the Raman Effect was recognized quickly by scientists all over the world. Professor R.W. Wood of Johns Hopkins cabled *Nature* to report that he had verified Raman's "brilliant and surprising discovery" in detail. He declared that this discovery which resulted from Raman's long and patient study of the phenomenon of light scattering is one of the most convincing proofs of the quantum theory.

When people made comparisons to the well known Compton effect, Raman prophetically stated that his effect which involved molecular scattering would have greater implications than the Compton scattering, which had to do with electron scattering of photon. Raman also recognized that his discovery was important to firmly establish the new quantum theory, because an explanation of the new radiation required the use of photons and their change in energy as they interacted with the atoms in a particular molecule. Raman also knew that there was a more important result, remarking in his 1930 Nobel Prize address that "... the character of the scattered radiations enables us to obtain an insight into the ultimate structure of the scattering substance."

By the late 1930s, the Raman Effect became an important method of nondestructive chemical analysis for both organic and inorganic compounds. The unique spectrum of Raman scattered light for any particular substance served as a "fingerprint" that could be used for qualitative analysis, even in a mixture of materials. Further, the intensity of the spectral lines was related to the amount of the substance. Raman spectroscopy could be applied not only to liquids but also to gases and solids. And unlike many other analytical methods, it could be applied easily to the analysis of aqueous solutions. It was a ubiquitous technique, giving

information on what and how much was present in a wide variety of samples.

The use of Raman spectroscopy as a basic analytical tool changed sharply after World War II. During the War, infrared spectroscopy was enhanced by the development of sensitive detectors and advances in electronics. Infrared measurements quickly became routine operations, while Raman measurements still required skilled operators and darkroom facilities. Raman spectroscopy was sidelined for a while because of Infrared spectroscopy. But with the advent of another great discovery in the 1960s, that of laser, interest in Raman spectroscopy was again revived. Now it finds application in many diverse fields like medical imaging and Biochemistry.

He was knighted by the British government in India and received the Nobel Prize in physics in 1930 (among all the Nobel Prizes awarded, this must have been the shortest in duration from the time of discovery). Three years later, Raman left Calcutta for Bangalore, where he was posted as the Director of the Indian Institute of Science (the first Indian to hold the post which was dominated by the British; his knighthood must have made it possible). There he continued his work on the Raman Effect and became interested in the structure of crystals, especially diamond.

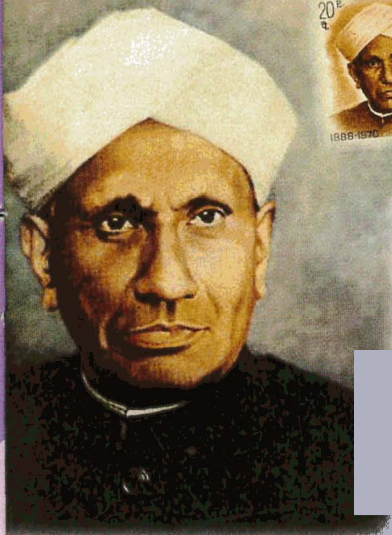
In 1934, he founded the Indian Academy of Science and began the publication of its *Proceedings*. While at the Indian Institute of Science (also called the Tata Institute after its founder), he tried to get many leading scientists to work with him. It was the time of the Second World War and many scientists of Jewish origin were fleeing from Germany. He succeeded in appointing the great theoretical physicist Max Born to an extraordinary chair of physics which he created at the Institute. But in inviting these scientists,

he did not take the permission of the Management of the Institute. For this and other reasons he was forced to resign the Directorship of the Institute, though he managed to retain his Professorship. Max Born was also humiliated by the British higher echelon of the Institute and he could not accept Raman's offer.

There was also a painful difference of opinion between these two great friends (Born and Raman) over Born's monumental work on crystal dynamics. Raman found Born's highly mathematical treatment in conflict with his more simplistic form of lattice dynamics. Raman could have simply presented his ideas as a simple physical approach to crystal dynamics. Instead, he mercilessly attacked Born's theory which made the protagonists of Born's idea to get deeper into it. Finally it turned out that Raman's simple approach was actually a small subset of a more comprehensive Born's theory. Born also inadvertently made a comment by criticizing Raman's "experimentalist" attitude. It is a pity that the entire incident resulted in a never healing bitterness between two great friends.

In 1948, he became director of the newly constructed Raman Research Institute, where he remained continually active, delivering his last lecture just two weeks before his death. His research interests changed in later years when he primarily investigated the perception of colour.

Raman was not fortunate like Niels Bohr, whose research center in Denmark was partly financed by the Carlsberg Brewery. He did not seek government funding since he hated any intervention by government officials. So he started a company called Travancore Chemical and Manufacturing Co. Ltd. in 1943 along with Dr. Krishnamurthy. The Company



Raman Research Institute



Raman studied at the Aloysius Anglo-Indian High School and proved to be exceedingly brilliant in his studies. At a rather young age of eleven, Raman passed his matriculation exam, and went on to complete his FA at the age of thirteen.

In 1934, he founded the Indian Academy of Science and began the publication of its Proceedings.

cremation for me. No mumbo-jumbo please." What a man!

Two days before Raman died, he told one of his former students, "Do not allow the journals of the Academy to die, for they are the sensitive indicators of the quality of science being done in the country and whether science is taking root in it or not." That same evening, Raman met with the Board of Management of his Institute and discussed (from his bed) with them any proceedings with regard to the Institute's management.

Raman passed away from natural causes early next morning, on 21st of November 1970. In 1986, the National Council for Science and Technology Communication (NCSTC) asked the government of India to designate February 28th as the National Science Day, to mark the discovery of the Raman Effect on 28th February 1928.

I joined the Raman Research Institute six years after the death of this great man. I missed the chance of interacting with him personally, and all the information I have just narrated, came to me through his close associates and information gleaned from existing sources. But I have one thing to be proud of – I still own the Olympus camera that he used to capture nature in all its glory (which I inherited through his son, Prof. Radhakrishnan, who was my friend and guide). This will be my prized possession among all my collections.

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during its sixty year history established four factories in Southern India. In 1947, he was appointed as the first National Professor by the new government of Independent India.

Raman's admiration for honesty and integrity is illustrated in a striking episode. While establishing the Raman Research Institute, Raman invited many young graduates to work with him. He even paid them the to-and-fro charges to ensure that really competent youngsters applied for the post. Once it so happened that a young graduate appeared for an interview conducted by him. Being a bit nervous, he fared very badly in answering Raman's fundamental questions, which of course, required a little bit of ingenuity that is not supplied in college education. (Clearly shows that college education in those days was no better than it is today!). Furiously Raman asked him to get out, chiding him for having come all the way from a distant place just to waste his time. The very next morning, Raman was surprised to find the same person loitering near the cashier's counter of his office. Raman angrily confronted the candidate and said: "Why are you still in my campus? I thought that I threw you out yesterday". The candidate said: "I am sorry sir, but your cashier while reimbursing my to-and-fro charges gave me some extra amount. I came to return it." Raman grabbed the young man's hand and said: "Please stay with me and be my assistant. I can teach Physics to any one. But I cannot teach honesty!"

The incident also illustrates what faith Raman had in himself as a great

teacher. His faith was fully justified since that student went on to become a noted physicist who made many fundamental contributions in lattice dynamics. (Many "great men" after hearing this episode, wanted to become part of it. They even claimed that they were with Raman when this incident took place, and it was they who persuaded the candidate to return the money! Some people are quick to seek cheap popularity!)

Raman was a kind hearted man. During a thunderstorm, one of his lab assistants had to leave for home late in the night. Raman promptly clothed him with his own woolen sweaters and gave him his own car to go home. He, however, hated the smell of liquor. So once when this same assistant entered his room after repairing a fault in his car, he mistook the smell of petrol as the smell of alcohol. He was about to fire this unfortunate man when one of his associates bailed him out by testifying that he saw him in the garage, servicing his car!

It is said that when he was offered a toast during the Nobel function dinner, he replied: "Gentleman! You have all seen the Raman Effect on alcohol. Please do not expect to see the alcohol's effect on Raman!"

Unlike most traditional Indians of his day, he never believed in superstitions and despised rituals. He never forced his sons to observe any of the traditional customs that were strictly followed by his family. On the night of his death, his wife asked him to take the name of god. He replied that he only believed in the spirit of man! Even on his death bed he gave a sermon about the mahatma, Jesus Christ and the Buddha and made a simple request to her: "Just a clean and simple