Life and Works of C.V.Raman

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Talk given to IX Standard school-children on 18th January, 2009

NCERT Program for NTS Awardees

Department of Physics, IIT-Madras

Dear friends:

It gives me great pleasure to be here with you this morning and to remember with you the contributions of one of the most illustrious sons of our great nation. Professor Chandrasekhara Venkata Raman is known to all of us, as such, and needs no introduction. Yet it is perpetually refreshing to reflect on his life, which is an infinite source of inspiration.

Professor Raman was born on the 7th of November 1888 in Thiruvanaikkaval near Trichinopoly. His mother's name was Parvathi Ammal, and father's name was Chandrasekhara Iyer. Chandrasekhara Iyer was a school teacher. Chandrasekhara Iyer and Parvathi Ammal had 8 children: 5 sons and 3 daughtors. Venkat Raman was the second child.

When Raman was 3 year's old, his father joined the Mrs.A.V.N. College at Vizagapatnam, Andhra Pradesh, as lecturer in Mathematics and Physics. He had procured an excellent collection of books on Physics, Mathematics and Philosophy. Chandrasekhara Iyer was a great lover of music, and played the violin extremely well.

Raman matriculated at his age of 11. At 13, he won a scholarship and joined the Presidency College, here in Madras. At 15, he passed his B.A. exam and got gold medals for Physics and for English. He passed his M.A. examination in 1907, at his age of 19. Being so young, it would surprise even his teachers to believe that this inconspicuous child could be a college student at all. His Professors in the Presidency College found him to be so knowledgeable, that they recognized that Raman did not need class-room instructions, and they exempted him from attending all science classes.

Raman was an extra-ordinary observer. At 16, while doing a routine experiment on his college spectrometer, he observed some diffraction bands. We all do these experiments, but rarely does anybody observes the findings critically, investigate the data, and analyze the same thoroughly. Raman's observations in that routine experiment constituted the subject of his first research paper, which was published by one of the most prestigious scientific journals of that time, namely, the Philosophical Magazine. In the very same issue, he published yet another article on a totally different topic: a short note on a new method he devised to measure a liquid's surface tension.

When Raman completed his B.A. education, it was suggested that he go to England for further studies. Raman did not go, however, since the Civil Surgeon of Madras did not find him to be physically fit to go to England. Raman did not regret it. In fact, he later said that he felt grateful to the Civil Surgeon for being responsible for him to stay back in India. Subsequently, after he completed his M.A., he took the Civil Services competitive exam for the Finance Department. Sure enough, he topped the score in that exam.

Around that time, he saw a 13 years old girl playing a Thyagaraja Keerthana on the Veena. Against all conventions of that time, he arranged his marriage with her. Her name was Lokasundari. In 1907, when Raman was just over 18 years old, he along with his wife went to Calcutta to join the Finance Department there as Assistant Accountant General. Within a week of his reaching Calcutta, he noticed, while he was on his way to work, a sign board which read "The Indian Association for Cultivation of Sciences", and this was to play a major role in his life, and in the very history of scientific culture in our country.

The Indian Association for Cultivation of Sciences was founded by Mahendra Lal Sircar about 12 years before Professor Raman was born. Mahendra Lal was an ambitious man, and he envisioned his institute to match a combination of the Royal Institution of London and the British Association. Unfortunately, even at the time of his death, around 1902 (or 1903?), Mahendra Lal was not quite successful in seeing his dream regarding his institute come a reality. When Raman joined the institute, Mahendra Lal's son, Amrit Lal was looking after the Indian Association for Cultivation of Sciences. Going back to our story, then, even as Professor Raman was working for the Accounts Department in Calcutta, on seeing the sign board of this institute, Professor Raman sought to use the facilities at the Association for Cultivation of Sciences, and he was readily granted permission to conduct his experiments there. Raman would put in several hours of work at the institute before he went to his Accounts Department office, and another several hours after he would return. His work was interrupted by a transfer to Rangoon for about a year in 1909, and also to Nagpur, in 1910. At both these places, he continued his experiments at his residence, with limited, insignificant facilities. Fortunately, in 1911, he was transferred back to Calcutta and could continue his work at the Indian Association for Cultivation of Science.

Raman had excellent organizational capacity, and had a great vision for the future of science in India. He started a Bulletin of the Indian Association in which original results of the research done would be published. This Bulletin grew, in 1917, into a full science journal, known as the Indian Journal of Physics. At the Association, Raman worked on a large number of problems. He would get interested in everything he observed, and indeed, a very keen observer he was. He would then go into the roots and attempt to understand the mechanism which governed the observed phenomena. This is the very method of science, and it is extra-ordinary, even in the context of several giants of science this century has seen, that there would be very few scientists who have indulged in such a variety of research problems. Thus, Raman followed up the recitations he heard his father play on the violin by his papers on the bowed string, the struck string, the maintenance of vibrations, on resonance, the sounds of splashes, and on music from heated metals! This, by no means, is a complete list of his research interests even in the field of sound and music alone! He discovered the overtones in the sounds of the mridangam and the tabla, thoroughly analysed them, and showed how the richness of these percussion instruments is so much superior to the normal stretched membrane of the western drums. Professor Raman, during that period, published a beautiful paper on the acoustical knowledge of the ancient Hindus, and had already become an international expert on sound and musical instruments.

In 1917, Professor Asutosh Mukherjee, who was the Vice Chancellor or the Calcutta University at that time, requested C.V.Raman to come out of his job at the Accounts Department and accept the prestigious Tarakanath Palit Professorship of Physics at the University of Calcutta. There was a hitch in Raman's appointment, however, since there was a regulation which required that a candidate for the Palit professorship must be trained in a foreign country! The self-respecting Raman refused to comply, and the distinguished Vice Chancellor changed the rules to appoint Raman.

It may be noted that this event shows the extra-ordinary pride Raman felt as an Indian. Very many years later, when Raman had received worldwide recognition, there was a similar event which I will narrate here, jumping our story a little bit. This was around 1933, when Raman was in Bangalore as the Director of what is now the Indian Institute of Science, then known as the Tata Institute. At that time, several German Physicists were fleeing their country to escape the atrocities committed by Hitler. Raman, who was opposed to young Indians going abroad for education, rather believed in getting great international stalwarts here. So he approached several of the German Physicists who were fleeing Germany and tried to attract them to take up permanent jobs in India.

Amongst the persons he approached are distinguished Physicists like Erwin Scroedinger and Max Born, both Nobel laureates. Unfortunately, as Schroedinger himself wrote in a letter, he had already accepted a job at Dublin when Raman's invitation reached him. Schrodinger also wrote in that letter, that he regretted that he could not settle in India, the land of the Upanishads. Regrettably, for attempting to get such distinguished scholars to India rather than sending our young students abroad, Professor Raman was removed from the Directorship of the then Tata Institute !

I will now go back to Raman's work in Calcutta. While he was Palit Professor at the Calcutta University, in 1919, Professor Raman became the Honorary Secretary of the Indian Association for Cultivation of Sciences and thus had two laboratories to work with. In 1921, Raman went to Oxford as a delegate at the Universities' Congress. One nagging phenomenon keeps surfacing as we reflect on virtually any aspect of Raman's life. This is his extra-ordinary observational capacity, and his keenness, enthusiasm, and total competence to understand his observations. During this visit to Europe, he visited the Saint Paul's Cathedral whose whispering gallery is famous the world over. Raman's excitement at the whispering gallery went well beyond that of anybody who ever visited that Cathedral, for Raman did a few small experiments and analyzed the results. His findings were far from trivial, and were published in two research articles in two of the foremost science journals, one in 'Nature' and the other in the 'Proceedings of the Royal Society'. On his sea voyage to Europe, Raman was struck by the blueness of the sea. Many of us believe that the blueness of the sea is due to the blueness of the sky. In fact, it was a person no less than Lord Rayleigh himself who said "the much admired blueness of the sea ... is simply the blue of the sky seen by reflection." Lord Rayleigh, as many of you would know, is the one who gave the first correct explanation for the sky being blue. Professor Raman did a simple experiment on his European voyage while on the ship and found that the blueness of the sea was not merely the blue of the sky seen by reflection, as Lord Rayleigh had maintained; rather, the blue of the sea was due to molecular scattering by the waters of the ocean. It was an extra-ordinary sight on the ship to see this turbaned Indian scientist conducting his experiments on the ship's deck with a simple polarizing nicol prism on sample's of sea water!

This, my friends, was in a sense the beginning of the most outstanding experiments ever performed in country, and lead to the work which brought the only prize in Physics our country has received.

On returning to India, Raman initiated research on 3 different lines:

1) The scattering of light by liquids,

2) the scattering of x-rays by liquids,

and 3) the viscosity of liquids.

Professor Raman's work on the scattering of light by liquids of course was the one which fetched him, and our country, the Nobel prize in Physics and came to be known as the RAMAN EFFECT.

Professor Raman’s work on the scattering of x-rays by liquids was also a pioneering one, and formed the basis of molecular structure studies in liquids. His paper along with collaborator Ramanathan has become extremely famous, and was a pioneering contribution made as early as in 1923. In the same year, Professor Raman advanced a theory of viscosity which has been used to explain the viscosity of polymers.

In 1924, Professor Raman was elected as a FELLOW of the Royal Society. At the meeting that was held to felicitate him, he expressed his appreciation for the honor he received. However, he went on to say that he did not consider this honor to be the ultimate and that he would, within 5 years, get the Nobel Prize for India. This confidence, determination, working toward specific goals, was characteristic of Raman's personality. It can certainly be argued that after all it could have been a matter of chance that he would not get the Nobel Prize, it may also be said that Raman had a fair idea of his research caliber. When you view his entire scientific activity, you find that it would rather be odd if a scientist of his caliber would miss the highest honors!

In 1922, Professor Raman published a monograph entitled "THE MOLECULAR DIFFRACTION OF LIGHT". The seeds of his subsequent work can be found in this work. In this monograph, for example, he has considered in details how energy could be transferred between a quantum of light and a molecule of liquid. He had expressed his conviction in this celebrated monograph, that the quantum nature of light must manifest itself in molecular scattering.

Perhaps, for my young friends here in today's audience, I must briefly explain what is meant by the QUANTUM NATURE OF LIGHT. This property of light is of central significance to the RAMAN EFFECT. Very often, we speak of light rays and consider the rays to propagate in space in essentially straight lines.

This explains how shadows are formed. Yet if we look at the borders of the shadows closely, we find an alternate distribution of light and darkness, which is absence of light. It is of interest to understand this phenomenon, caused by DIFFRACTION of light at the edges of an object. The INTERFERENCE or DIFFRACTION of light is generally explained in terms of Huygens' wave theory of light. The alternate theory of light was due to Isaac Newton, the illustrious contemporary of Huygens, and Newton's theory is known as the corpuscular theory of light.

Corpuscles mean particles, and so we have a ‘wave theory’ and a ‘particle theory’. We are forced by our experience in assigning a meaning to these words, 'particles' and 'waves'. We perceive particles, such as dust, chalk powder etc. to be of a totally different nature compared to what we call as waves, such as ripples or waves on the ocean's surface. We, in our normal vocabulary, never would wish to mix up these two terms: 'PARTICLES' and 'WAVES'. This view of nature, in which we consider the particles and waves to belong to two separate categories, "totally belonging to disjoint concepts, is known as the 'CLASSICAL' view. However, toward the very end of the nineteenth century, a desperate German Physicist, Max Planck, proposed that light must have a corpuscular nature. This model of light envisages light energy to be kind of bundled up the way particles seem to be bundled up. The technical word for such a bundle is "QUANTUM" and thus the quantum theory of light uses a particle description of light. The reconciliation of the wave theory and the particle theory has emerged as a major triumph of modern Physics, and forms the subject of QUANTUM MECHANICS. Another and equivalent way of looking at this phenomenology is to recognize that one must know both the position and the velocity of an object to predict where it would be after a certain time even if it were going at constant velocity, but one must reconcile with the fact that a measurement of the position and velocity alone can yield this information and the consequences of the interaction between the target and the probe that is involved in the measurement cannot be escaped from. An essential consequence is that the simultaneous accurate knowledge of the position and velocity (more precisely the momentum) is then not accessible, and this consequence is at the heart of what is known as Heisenberg’s uncertainty principle which involves the very same concepts as are involved in the wave-particle duality mentioned above. The development of quantum mechanics is a very fascinating story, and how much ever I would love to tell you that story, since it is one of the most interesting stories, I will have to refrain myself from getting into the details of quantum mechanics. However, my young friends must recognize the fact that in the 1920's, the quantum theory was still being formulated. Several pieces of evidence, experimental, conceptual, mathematical etc. were proposed to establish the quantum theory. The quantum theory was conceived in the works of Planck in 1899 and of Einstein in 1905, but the developments continued through the next two decades overlapping with the very important developments in the 1920s when Raman was working tirelessly in his Laboratory in Calcutta (now Kolkata). The RAMAN EFFECT is also a major piece of evidence in favor of the quantum theory.

In the month of April 1923, Professor Raman's distinguished student, K.R.Ramanathan, initiated some experiments on the scattering of light by water. The experiment was done using sunlight, and the scattered light was seen as a track in the transverse direction, and using a system of filters, the scattered light was examined. The filters were arranged in such a way that when the incident light was passed through one of the two complementary filters and the scattered light was viewed through the other filter, no track should have been visible at all. Some track however could be observed, and was attributed to a weak fluorescence of the impurity molecules. Ramanathan himself wrote later that it was Professor Raman himself, and none other, who was not satisfied by the explanation based on the fluorescence model and that he (Raman) wondered if the track observed was due to some characteristic molecular scattering. The same effect was observed later in many organic liquids by K.S.Krishnan, another of Raman's distinguished students.

Although I will not go into the details, there was a certain similarity in the explanation Raman had in mind with that of what is known as the Compton Effect. In the winter of 1927, Professor Raman went to Waltair for a short visit; he derived a formula for molecular scattering now known as the Compton-Raman formula.

In January 1928, another associate of Professor Raman, Venkateswaran, observed that in pure glycerin, the scattered light was greenish in color, instead of the usual blue. Moreover, the radiation was strongly polarized. In the last week of January, Professor Raman asked K.S.Krishnan to repeat these experiments under more carefully controlled conditions.

K.S.Krishnan was at that time doing completely theoretical work and Professor Raman advised him that it was not healthy for a man of science to stay out of touch with actual experiments for any significant length of time. Krishnan also reported the same type of findings as Ramanathan did, and Professor Raman personally verified all the observations.

Professor Raman was extremely excited about the findings, since he understood exactly what this just discovered phenomenon was. On 16th February, Raman sent a note to Nature, suggesting that the modified radiation observed in these scattering experiments could be due to certain molecular fluctuations. Yet, however, the phenomenon was not fully understood. On the 27th February, Raman set up an experiment in which he decided to view the track earlier thought to be due to fluorescence using a direct vision spectroscope. The experiment could not be completed that evening, as by the time~ the experiment was set up, the sun had set! Next morning, February 28th, 1928, when the experiment was done personally by Professor Raman, he found that the track contained not only the incident color but also another one separated by a dark region. This was the very first observation of what is known as the RAMAN EFFECT.

An announcement was made to the Associated Press on 29th February (in the leap year) and Professor Raman sent a note to Nature on March 8th announcing his discovery along with a complete explanation.

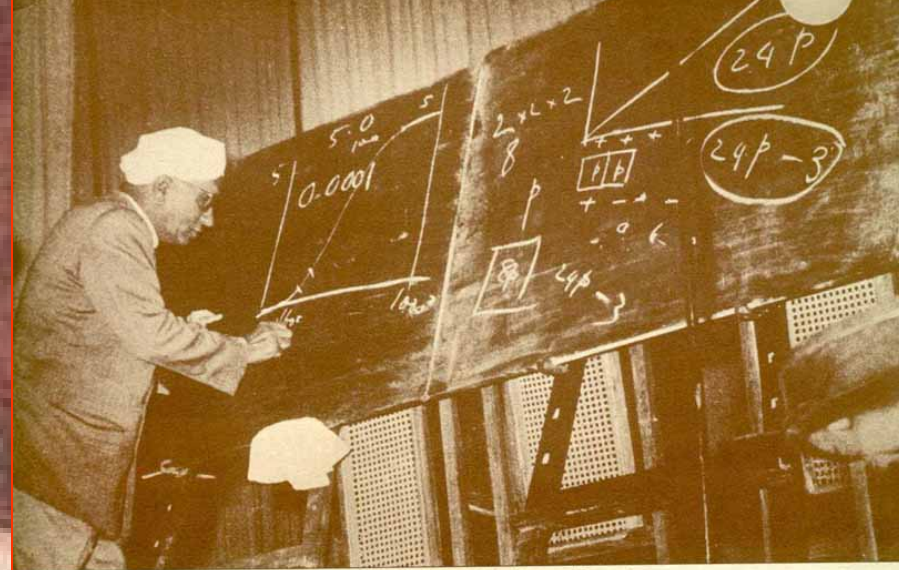
Several laboratories in the world, on coming to know of this experiment, repeated such measurements and confirmed the findings. The recognition that followed in terms of the Nobel prize was almost inevitable, despite the fact that Raman was an Indian. As you would know, the Nobel prize for Physics is given each year at Stockholm, Sweden, on the 10th of December, and the award is announced for that year about a month in advance. The Nobel committee meetings are held in great secrecy and between the time of announcement and the award ceremony, it would be very difficult to manage a journey to Sweden at such a short notice. Raman, however, made the trip, as even before the award was announced, he had already booked 2 tickets on a steamer, for himself and for his wife.

The Raman effect involves an exchange of a quantum of energy between a molecule and the electromagnetic radiation. Molecular energy levels are quantized, and this means that a molecule cannot possess an arbitrary amount of energy. The energy may be due to various reasons, and one may thus speak of the electronic energy, rotational energy or the vibrational energy of the molecule. A molecule may undergo transition from one energy state to another only by absorbing or emitting a discrete amount of energy. Raman Spectroscopy involves the study of such transitions. This is now an extremely specialized branch of spectroscopy and has undergone enormous developments. Raman spectroscopy is rarely done using sunlight as a source. Now, LASER radiation is employed and it has very many fascinating applications, and the technique is known as the Laser-Raman Spectroscopy.

Raman's contributions to Physics go well beyond what he is best known for. He remained very active right until his death in 1970. He was a great naturalist, and was a scientist to the core. He was strongly nationalistic. He demanded rigorous discipline in work habits. And most importantly, he had a vision for science in India, to make India self-reliant.

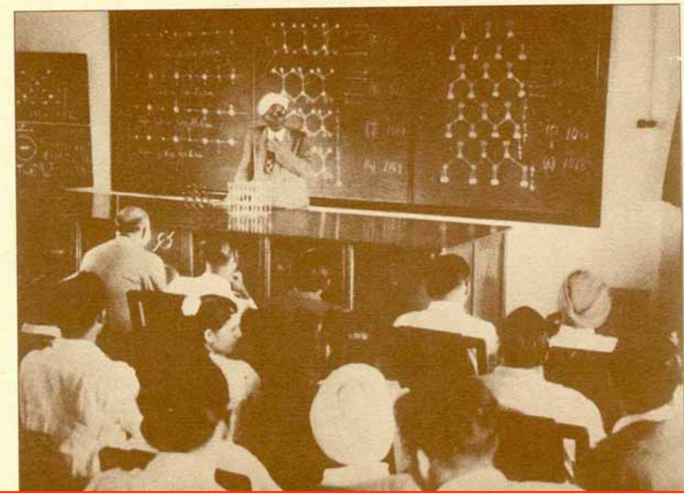
I am very grateful to NCERT, and to each one of you in this audience this afternoon, to have given me an opportunity to spend this time remembering Raman along with you. Thank you all very much.

This article leans heavily on the special ‘Raman Centenary’ volume brought out by PHYSICS NEWS (Vol. 19, No.4, December 1988). Besides, you can find lot of interesting articles on Raman’s life and work on the internet, of which I specifically draw your attention to an article by Dr. Subodh Mahanti published by Vigyan Prasar and available at the internet link http://www.vigyanprasar.gov.in/scientists/cvraman/Raman1.htm . The article by Rajinder Singh and Falk Riess explains the compelling reasons why Raman’s work got such early recognition by the Nobel committee, considering that he was awarded the Nobel prize for 1930, just two years after the work was published. This article is available at the internet link http://www.iisc.ernet.in/~currsci/nov10/articles33.htm . Appended below are some pictures I have taken from the internet, including from the sources referred to above.

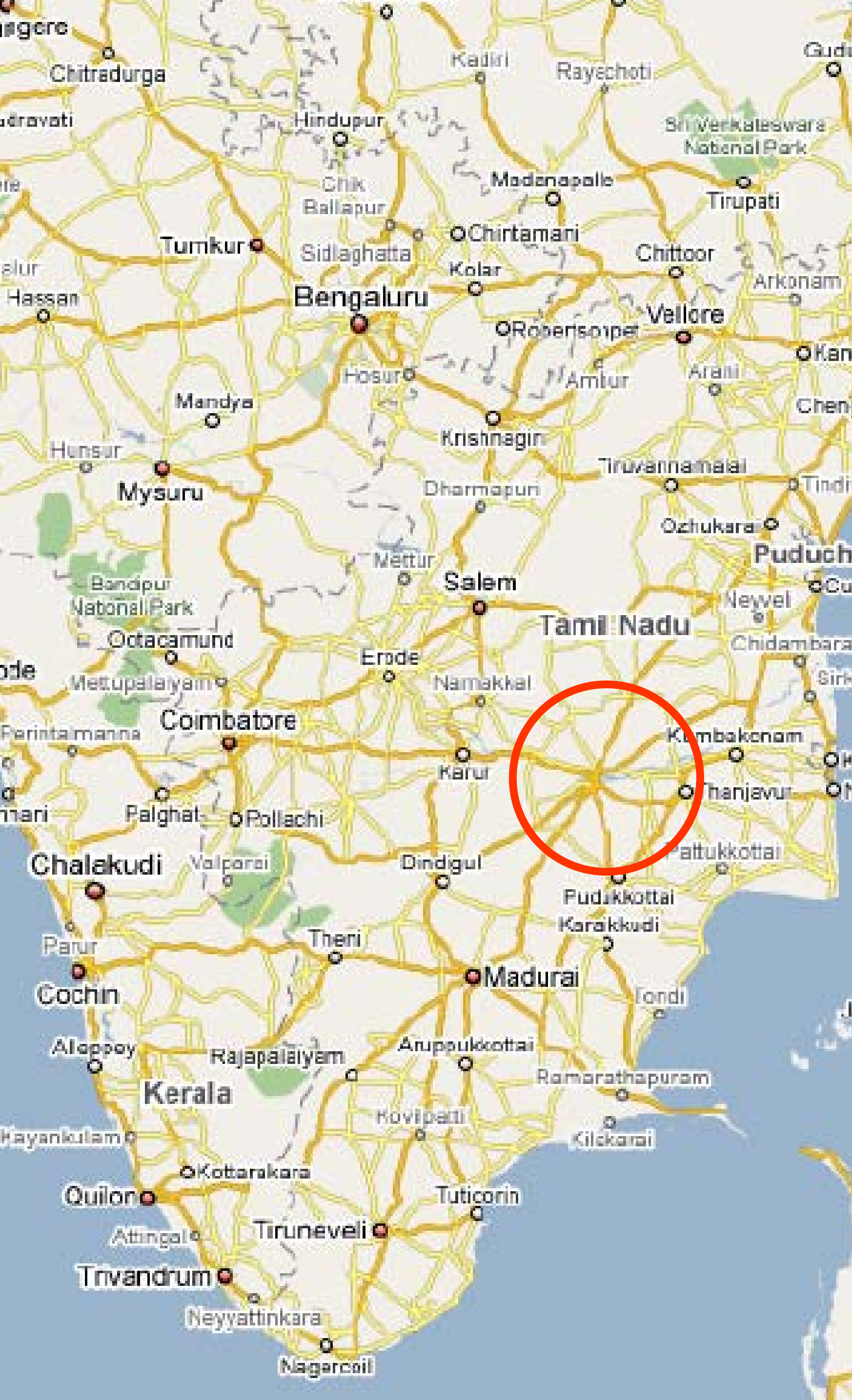


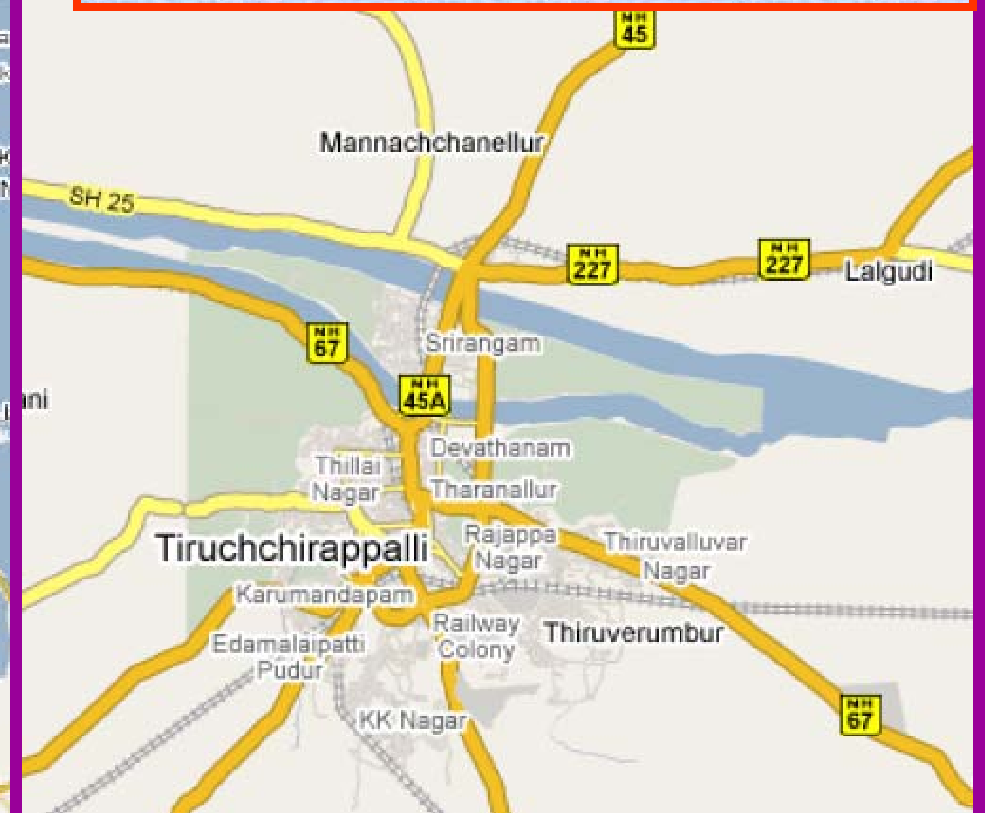
Raman expounding his crystal dynamics

Gandhi Memorial Lecture



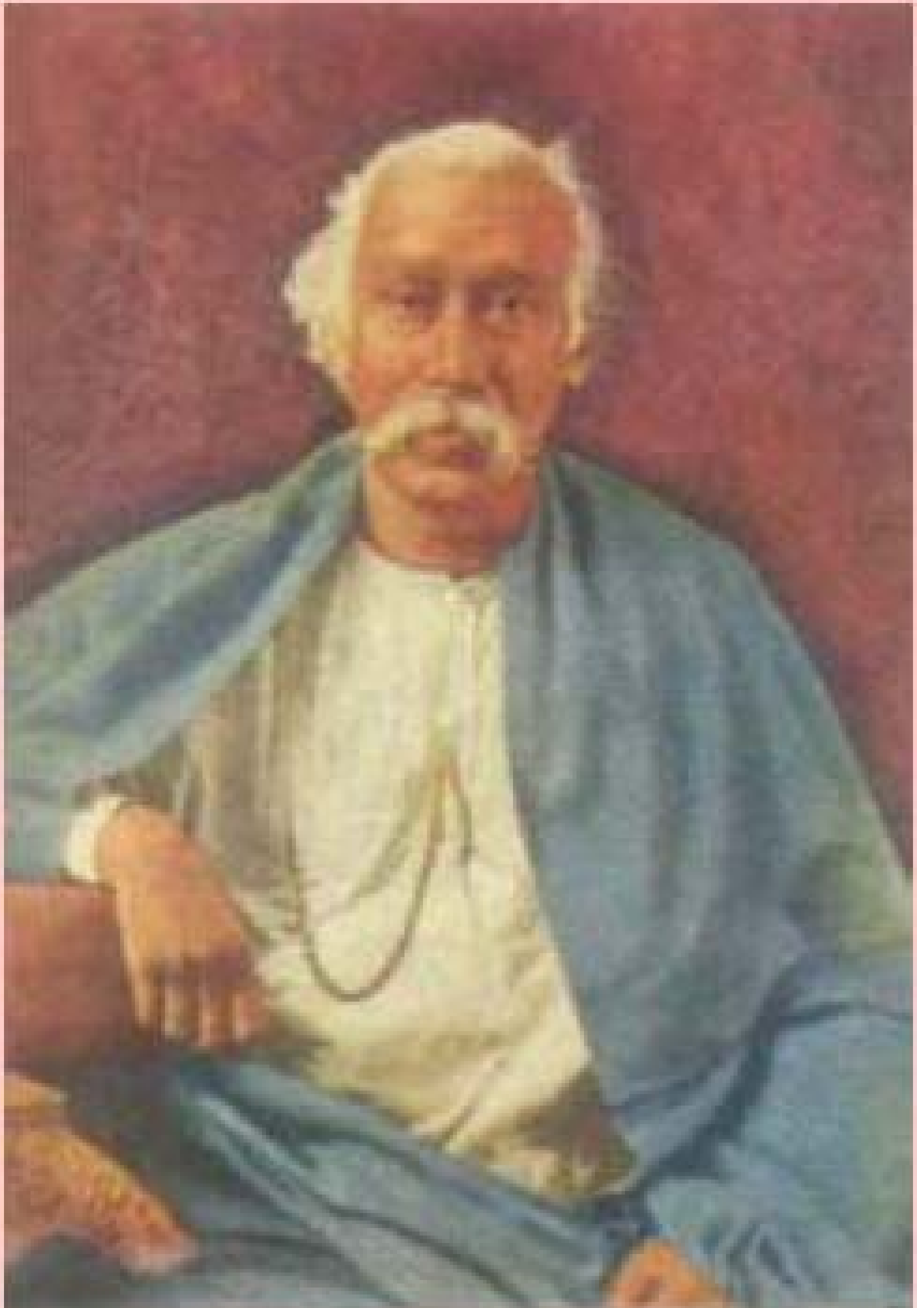
Chandrasekhara Venkata Raman 7/11/1888 – 21/11/1970





The house where Professor C. V. Raman was born on 7th November 1888

 R. Chandrasekhar Iyer (Raman's Father)	 Parvathi Ammal(Raman's mother)

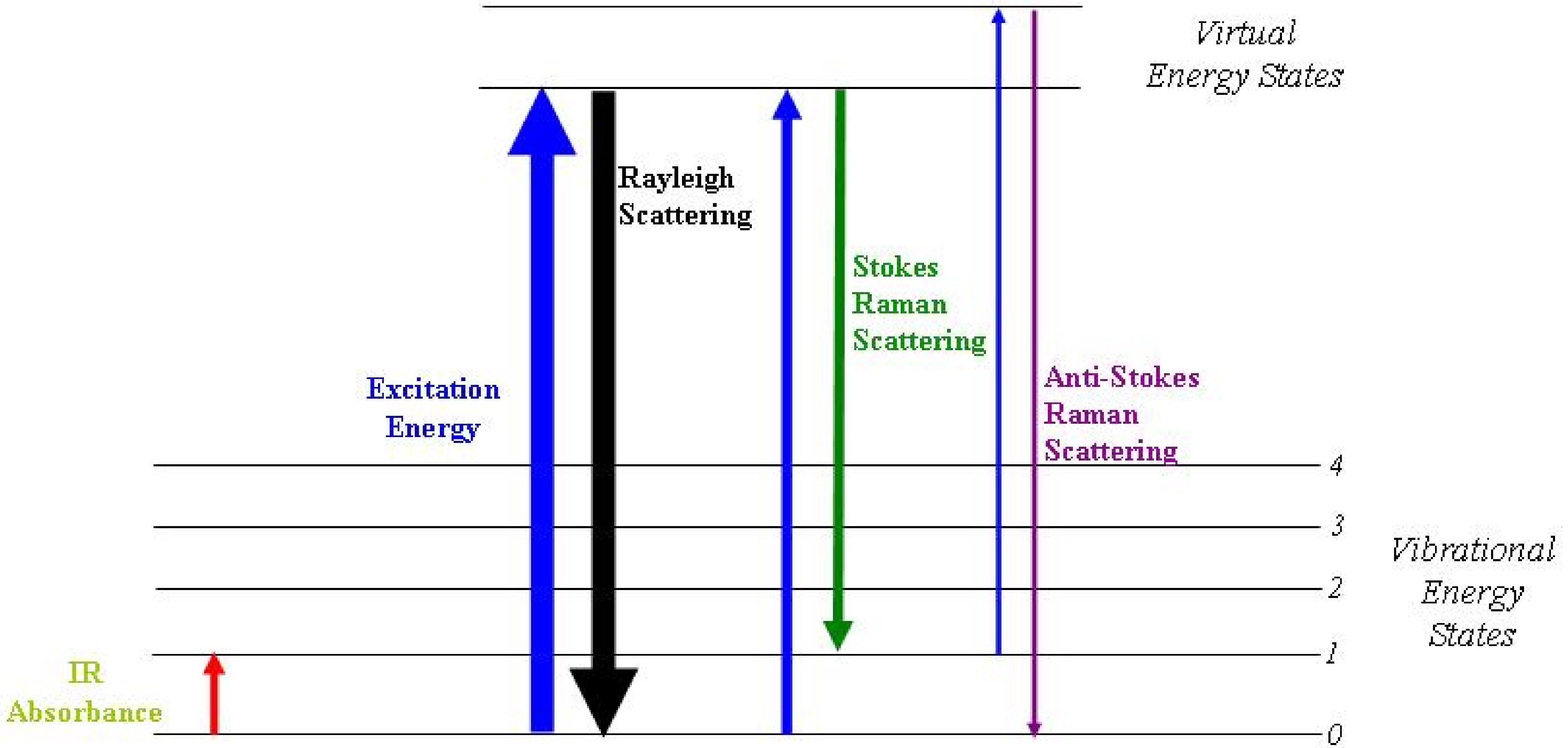


Mahendra Lal Sircar

Indian Association for
Cultivation of Sciences,
Kolkata

Founded in 1876,
12 years before Raman was
born

Indian Institute of Science, Bangaluru



Virtual
Energy States
Rayleigh
Scattering
Stokes
Raman
Scattering
Anti-Stokes
Raman
Scattering
Excitation
Energy
4
3
2
1
0
Vibrational
Energy
States
IR
Absorbance

Table I. Names of the persons who recommended Raman alone or Raman with others for the Nobel prize for the year 1930 (ref. 10)

Nominator	Candidate/s
E. Bloch (Paris)	W. R. Wood* and C. V. Raman
N. Bohr (Copenhagen)	Wood or Wood and Raman
O. Chwolson (Leningrad)	Half for Raman and the rest for Landsberg and Mandelstam
J. Perrin (Paris)	Raman or Raman and Heisenberg
F. L. de Broglie (Paris)	Raman
H. M. de Broglie (Paris)	Raman
R. Pfeiffer (Breslau)	Raman
J. Stark (Grosshesselohe)	Raman
E. Rutherford (Cambridge)	Raman
C. T. R. Wilson (Cambridge)	Raman

*W. R. Wood (1868–1955) was famous for his work on fluorescence and resonance radiation.

Sir C. V. Raman and the story of the Nobel prize

Rajinder Singh and Falk Riess

http://www.iisc.ernet.in/~currsci/nov10/articles33.htm

CURRENT SCIENCE, VOL. 74, NO. 4, 25 FEBRUARY 1998

Draft of Max Born's letter to C.V.Raman

Feb. 18th, 1934. 246, Hills Road, Cambridge.

Dear Professor Raman,

I have received your kind letter ~~from~~ of Jan 21st, and I wish to thank you very much for your offering me a position at your Institute. It is, indeed, a great honour to me, and I have considered it very carefully. If I would be 10 years younger I should not hesitate to accept it. But being a little over 50 it is not quite easy to go into an unknown country, very far from Europe, and with a very different climate. I would like to explain you my position quite frankly.

Box. The first part of Born's letter to Raman.

In 1935, he spend several months working at the Indian Institute of Science in Bangalore. He collaborated there with C.V. Raman

Wolfgang Pauli and C.V.Raman

C.V.Raman, with Werner Heisenberg

Niels Bohr and Raman

Raman with Mahatma Gandhi and Mahadeo Desai

Loksundari with Kasturba Gandhi

Scientific Papers of C.V. Raman: Optics of Minerals And Diamond (Hardcover)

Hardcover: 766 pages ; **Publisher:** Oxford Univ Pr (Sd) (July 1989)
Language: English, **ISBN-10:** 8185324042 , **ISBN-13:** 978-8185324043

To C.V. Raman color was an obsession. The visual impact that the blue of the Mediterranean had on him culminated in his discovery of the Raman effect. This volume contains 79 papers he published on a variety of topics, 39 of which deal with color in Nature. All the optical phenomena in his repertoire were necessary to explain the flashing rainbow colors of the plumage of birds. 16 papers deal with diamonds: The beauty of their geometric form, and their lustrous curved faces bring out clearly that many specimens exhibit a symmetry lower than the highest in the cubic class. Twenty papers deal with miscellaneous topics in which Raman was interested from time to time. His phenomenological theory of viscosity which was so useful to the polymer chemist, his classic studies of impact between two bodies, and his pioneering work of the mechanism on fracture of solids are all dealt with in this volume.

Raman showing diamonds to J.D.Bernal

Raman and R.A.Millikan

THE DIAMOND*

By Sir C. V. Raman

(*Memoir No. 86 from the Raman Research Institute, Bangalore-6*)

Received September 5, 1956

* A lecture delivered at the Federal Polytechnic Institute in Zurich and at the Universities of Freiburg and Bonn early in July 1956, following the address on "The Physics of Crystals" given at Lindau in June, 1956. The latter address has been published in these *Proceedings* (Memoir No. 85 of the Institute), but the present memoir may be read independently of the same.

1. Introduction

The many remarkable properties which diamond exhibits, taken in conjunction with the simplicity of its crystal structure and composition, make it a substance of quite exceptional interest to the physicist. In the hope that investigations made with it would result in significant contributions to knowledge, a collection of some five hundred diamonds was built up in the course of years and used by the present author and his collaborators in an extensive series of researches. It would not be possible in this lecture to survey all the topics investigated. We shall confine ourselves to the consideration of some results which have emerged from our studies and which are of fundamental significance for the physics of the solid state.

Stamp issued: 21-11-1971

The tree planted on the site at the campus of Raman Research Institue where Raman was cremated

21-11-1970