C. V. RAMAN MEMORIAL LECTURE — 1978

C. V. Raman

by

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C. V. RAMAN

I deem it a great honour to have been invited to deliver the first Raman Memorial Lecture. It was suggested that I should talk about Prof. Raman as it would be an appropriate subject this year, the 50th anniversary of the discovery of the Raman effect.

According to the modern view of science, nature can only be described. It cannot be explained. Like many extraordinary natural phenomena, Raman can only be described; he defies explanation.

This talk is not going to be a sociological or psychological study of Raman. I was his student and I knew him well for more than 25 years. For this very reason mine is likely to be a prejudiced view.

Venkata Raman was born on the 7th November 1888 in the small village of Thiruvanaikkaval near Trichinopoly (in Tamil Nadu). His mother was Parvathi Ammal. His father Chandrasekhara Iyer was a teacher in a local school. They had eight children, five sons and three daughters. Apparently Chandrasekhara Iyer did not believe in family planning. Even if he did, and had stuck to the statutory limit, Raman would still have made it – as he was the second child, but the present speaker would not have been here to tell this story.

When Raman was three his father accepted the post of lecturer in mathematics and physics in Mrs.A.V.N. College, Vizagapatnam, (in Andhra Pradesh). It is interesting that in spite of a small salary (Rs.85/- p.m.)

and a large family to support, Chandrasekhara Iyer had a good collection of books on physics, mathematics and philosophy written by the masters. He is also said to have played the violin exceedingly well.

Raman matriculated at 11, passed his F.A. (now-a-days called PUC or intermediate) at 13, won a scholarship and joined the Presidency College, Madras. He passed his B.A. at 15 in the first class winning gold medals in English and Physics. He passed the M. A. examination at 18 in January 1907. There is a photograph of him taken when he was in the Presidency College; a thin unimpressive boy with a dhothi draped in the South Indian (cylindrical) style, a cap and no chappals on his feet. There is a story that one of the professors at the college could not believe that this inconspicuous little lad was a student of the Presidency College. He asked Raman whether he had come there by mistake and caused general laughter in class. Very soon his professors found him so remarkably intelligent that they exempted him from attending all the science classes as they felt he had nothing to learn from them. (What understanding professors they were in those days!)

Some of the certificates that his teachers gave Raman are interesting: "The best student I have had in thirty years". "An unusual appreciation of English literature". "A facility in idiomatic expression". "Possessing great alertness of mind and a strong intellectual grasp". "A young man of independence and strength of character", etc.

At the age of 16 while measuring the angle of a prism using a college spectrometer – as thousands of us have done – Raman observed some diffraction bands. He investigated these and they formed the subject of his first publication in The Philosophical Magazine (London) in

1906. This was followed by a note in the same journal on a new experimental method of measuring surface tension.

These papers were communicated by the author himself and contain no acknowledgement of help received from any one. It is also important to note that the Presidency College was at that time a teaching institution with no tradition whatsoever of research.

When he passed his B.A. Examination his teachers suggested that he should go to England for further studies. But the Civil Surgeon of Madras ruled it out by disqualifying him medically saying that the rigours of the English climate would kill him. Raman is known to have said later "I shall ever be grateful to this man". In 1906 after his M.A. his teachers advised him to appear for the competitive examination which chose civil servants for the Finance Department. He passed the examination topping the list again.

Against all conventions of the time he arranged his own marriage with Lokasundari, who was then 13 years old. The story has it that on the first occasion he saw her, she was playing on the veena the Thyagaraja Keertana "Rama ni samanam evaro". We shall never know whether it was by intent or by accident. Anyway, she insists that she still does not know if Raman married her for the extra allowance of Rs.150/- which the Finance Department gave to its married officers!

In 1907 the young couple went to Calcutta. He joined the Finance Department as Assistant Accountant General. He was then $18\frac{1}{2}$ years old.

They rented a house in Scots Lane, off Bowbazaar Street. Within 6 or 7 days of his reaching Calcutta,

while on his way to work by tram, he saw a sign which read The Indian Association for the Cultivation of Science. The address was 210, Bowbazaar Street. On his way back he knocked on the door, it was opened, we are told, by one Ashutosh Dey who was to be Raman's assistant for 25 years, the faithful Ashu Babu. Raman saw a dusty lecture hall and a large laboratory with a lot of even dustier equipment, mostly of the demonstration type.

Ashu Babu took Raman to Amrita Lal Sircar, the Secretary of the Association, who promptly handed over the keys of the Association to Raman when he heard of his plans to use it for research.

The Association had been established in 1876 by Amrita Lal's father Mahendra Lal Sircar, a man of vision, who wanted to have an institution which was a combination of the Royal Institution of London and the British Association. It started off well. At every annual meeting Mahendra Lal advocated the importance of the cultivation of science by original research. There were many popular and scientific lectures in the early days but no research of any type. Subsequently the institution had decayed, and in 1902 a despondent Mahendra Lal had declared, "I do not know how to account for the apathy of our people towards the cultivation of science" A few weeks before his death he stated "Younger men must come and step into my place and make this into a great institution".

At this time Raman had just passed his B.A. Examination. In three years he was to discover the Association and turn 210, Bowbazaar Street into one of the important centres of original research in the world.

Young Lokasundari tells us of the routine – 5.30 a.m. Raman goes to the Association. Returns at 9.45

a.m. bathes, gulps his food in haste, leaves for his office, invariably by taxi so that he may not be late. At 5 p.m. Raman goes directly to the Association on his way back from work. Home at 9.30 or 10 p.m. Sundays, whole day at the Association. Truly, not an exciting life for a young bride.

She tells delightful stories of those days. There was one, of her going to the beautiful church at the end of Scots Lane when exploring the neighbourhood – but the brahmin cook (they had one, remember the Rs.150/- married allowance) left because he did not want to have any truck with people who go to church!

There is an interruption to Raman's work at the Association but not to his scientific activity. He is transferred to Rangoon (1909) and Nagpur (1910). At both places he converts his home into a laboratory and continues his work. He is back in Calcutta in 1911.

He and Ashu Babu are the only workers at the Association. Even so publications pour out. He starts the Bulletin of the Indian Association wherein he publishes massive monographs. In 1917 the Bulletin becomes the Proceedings and much later the Indian Journal of Physics.

What are the problems he tackles? It is remarkable that every one of them is connected with his direct experience thus arousing his curiosity. He has heard his father play the violin. He has worked with the sonometer and done Melde's experiment in college. So follow his papers on the bowed string, the struck string, the maintenance of vibrations, resonance, aerial waves generated by impact, the sounds of splashes, the singing flames, music from heated metals and many others.

Ashu Babu is his only collaborator and his name appears as a joint author in many papers. Raman is proud that there is a paper in which A. Dey is the sole author; published in the Proceedings of the Royal Society by his Ashu Babu who has never entered the portals of a university!

He investigates whether his feeling that the veena produces the most exquisite musical sound is due to sentiment or has a sound physical basis. The bridge of the veena is so cunningly constructed that the Helmholtz law, that the position at which the string is plucked cannot be a node, is violated. Thus this instrument produces innumerable harmonics making its sound closest in harmonic content to the human voice.

He knows that the normal stretched circular membrane as found in the western drum is "unmusical and just a noise producer". His sharp ear detects musical overtones in the sound of the mridangam and the tabla. He discovers that the heterogeneous loading of their membranes can produce harmonics – so that in the hands of the masters, the Indian drum is similar to a stringed instrument.

He publishes a beautiful paper on acoustical knowledge of the ancient Hindus, for the Ashutosh Mukherjee commemoration volume. He has become a world authority on sound and musical instruments.

A little earlier Sir Ashutosh Mukherjee, the Vice-Chancellor of the Calcutta University, offers him the Palit Chair of Physics. Raman decides to accept the offer for a salary less than what he is getting.

It is of some interest to know whether at this time he was successful as a Finance Officer. Apparently he

was, for he has been congratulated many times by his "superiors" for his outstanding work. They are reluctant to let him go. The Member (Finance) of the Viceroy's Council writes: "We find Venkataraman is most useful in the Finance Department being, in fact, one of our best men".

Raman's decision produces consternation in the establishment. There may soon be Indianisation, they tell him. As one of the best officers, he may even end up as Member (Finance) in the Viceroy's Council – who knows? But Raman's mind is made up.

There is a problem, however, because one of the requirements for appointment to the Palit Chair is to have been trained abroad. Raman refuses to go to England to be "trained". The impasse is broken by Sir Ashutosh changing the provisions of the endowment. What an administrator!

In 1919 Amrita Lal Sircar died and Raman became the Honorary Secretary of the Association having thus two laboratories to work in. He takes research students for the first time.

Under pressure from Sir Ashutosh he goes to Europe in 1921, as a delegate to the Universities' Congress held that year in Oxford. During this brief visit he meets the most famous scientists of England, J. J. Thomson, Rutherford, Bragg senior and others.

Raman tells a story later how moved he was when Rutherford recognised him sitting in a back bench at a lecture and asked him to come and sit next to him.

Like any good tourist he takes in the sights of London and visits St. Paul's Cathedral. He marvels at its

whispering gallery, does a few experiments, and publishes two papers – one in Nature and the other in the Proceedings of the Royal Society.

It was on this voyage that Raman came face to face with the grandeur of the Mediterranean sea, its beauty, its moods and in particular its blueness. The more he saw of it, the more did his wonder grow.

Lord Rayleigh, who had explained the blue of the sky as due to scattering by the molecules in the atmosphere, dismissed the blue of the sea with the statement "The much admired dark blue of the deep sea ..... is simply, the blue of the sky seen by reflection". Raman demolished this idea by an extremely simple experiment during the return voyage. He quenched the reflection of the sky in the sea by observing it at the Brewsterian angle through a polarising nicol prism. Even with the sky reflection so extinguished, he saw the surface of the sea glowing with a vivid blue which appeared to emerge from inside the water indicating that the blueness of the sea was due to scattering by the water.

What a sight he must have been on the ship – this turbanned brown Indian, with his nicol prisms and cardboard tubes, running from side to side of the ship, collecting sea water in bottles from the depths of the oceans. All this while others were busy playing shuttlecock and battledores – the real mad scientist of fiction.

Even on board ship he felt that the Einstein-Smoluchowski concept of thermodynamic fluctuation – which was developed to explain special optical phenomena near the critical point – could be extended to explain molecular diffraction in liquids. On his return to India he started three most fruitful lines of investigation:

1. The scattering of light by liquids.
2. The scattering of x-rays by liquids.
3. The viscosity of liquids.

Many here may not know that the earliest work on the scattering of x-rays by liquids was done in India. Raman and his group developed an effective theory and confirmed the shapes of many molecules and deduced the nature of their aggregation in the liquid state. Raman once said wistfully "We were so preoccupied with light scattering that we did not apply the idea of Fourier transforms to x-ray scattering in liquids although we were so close to it". This was done later by Zernicke and Prins in 1927 – The famous Raman-Ramanathan paper was in 1923.

In 1923 he advanced a theory of viscosity which was quite a success. It was used by Staudinger the famous polymer chemist to explain the viscosity of polymers.

Within a few weeks of his return from England he (and Seshagiri Rao) had measured the intensity of the molecular scattering of light from water. They established that the Einstein-Smoluchowski concept of thermodynamic fluctuations could be extended to explain molecular scattering almost quantitatively. As a result many of his students were put to studying molecular scattering in liquids and vapours.

It was in 1922 that he wrote and published his monograph "The Molecular Diffraction of Light". In it he raised such questions as to what would happen in a black body enclosure if the exchange of energy took place by molecular scattering. He considered in detail how energy could be transferred between the quantum of light and the molecule. He seems to have been convinced that the quantum nature of light should reveal

itself in molecular scattering. We note that all this was a year before the discovery of the Compton effect.

In April 1923 K. R. Ramanathan, the oldest and among the most distinguished of Raman's students, at Raman's suggestion, made a serious study of the scattering of light in water. Sunlight was focussed on the liquid and the scattered light was seen as a track in the transverse direction. A system of complementary filters was devised, each filter completely cutting off the light transmitted by the other. When the incident light was passed through one, and the scattered light viewed through the other, no track should have been visible, if there had been no change of colour in the process. But the track could be observed. This was attributed to a "weak fluorescence" due to impurities which were believed to be present. This "weak fluorescence" was not completely depolarised (as true fluorescence should have been) and that the amount of depolarisation changed with wavelength.

Ramanathan wrote much later: "Raman was not satisfied with the explanation that it was due to fluorescence. He felt that it was characteristic of the substance and wondered whether it might not be akin to the Compton effect in x-ray scattering" (where a change in wavelength of x-rays scattered by atoms had just been discovered that year). Even after repeated slow distillation of the liquids in vacuum the "weak fluorescence" persisted undiminished. The same effect was also observed later in many organic liquids, by K. S. Krishnan another of Raman's distinguished students who had just joined him.

In winter of 1927 Raman went on a vacation (or perhaps a lecture tour) to Waltair. The Compton effect was on his mind. He had calculated that the true

Compton scattering could not be observed at optical wavelengths. He considered the interaction of x-rays with the electrons of the atom – and using the concept of fluctuations, which was so successful in explaining the molecular scattering, he derived the relationship now famous as the Compton-Raman formula. The derivation was completely classical wherein Raman showed that the coherent scattering (corresponding to Thomson scattering in x-rays and to Rayleigh scattering in light) is proportional to the square of the number of electrons in the atom whereas the incoherent scattering (Compton scattering) is proportional to the number of electrons.

In January 1928 Venkateswaran who was on the task of purifying many liquids made the remarkable observation that in pure glycerine the scattered light was greenish in colour instead of the usual blue, and the radiation was strongly polarised.

In the last week of January Raman apparently decided to settle the issue. He asked K. S. Krishnan who has been doing excellent theoretical work on mechanical, electric and magnetic birefringence to take up experimental work again and to follow up Venkateswaran's observations. Raman persuaded Krishnan that it was not healthy for a scientific man to get out of touch with actual experimentation for any length of time (Krishnan's last experimental work was done 18 to 20 months before).

Krishnan set up the experiment for the study of the scattering of light in organic liquids and vapours – but this time he used larger lenses (7 inches diameter) so the intensity of the track was very much greater. On the 7th February he noticed that all his liquids exhibited the famous "weak fluorescence" observed by Ramanathan and further that the polarisation of the "fluorescent"

light was greater the smaller the anisotropy of the molecule.

Professor Raman (according to Krishnan) personally verified that all the liquids exhibited this phenomenon. He records that Raman rushed to his house quite excited to tell him that he was certain that their observations in the morning were related to the Kramers-Heisenberg process they were looking for all these years. On the 16th February they sent a note to Nature repeating the arguments used in Raman's classical derivation of the Compton effect and suggesting that "the modified radiation could arise from the fluctuations of the molecules from the normal state".

While the analogy with the x-ray case had been made much closer, it was apparent that the phenomenon was not fully understood and the observations continued, Raman making most of them himself.

On the evening of the 27th Raman decided to view the "fluorescent track" through a direct vision spectroscope but by the time Ashu Babu set it up the sun had set. Next morning the first observation was made of what is now known as the Raman effect. The spectroscope showed that the track contained not only the incident colour but at least another separated by a dark space.

Ashu Babu was immediately asked to set up a mercury arc, a light source known for its sharp monochromatic lines. Using a filter in the incident light which cuts off all the visible light longer than the indigo 4358 A.U. line the direct vision spectroscope showed not one but two sharp lines in the blue-green region.

The announcement of the discovery was made to the Associated Press the following day, the 29th of February 1928.

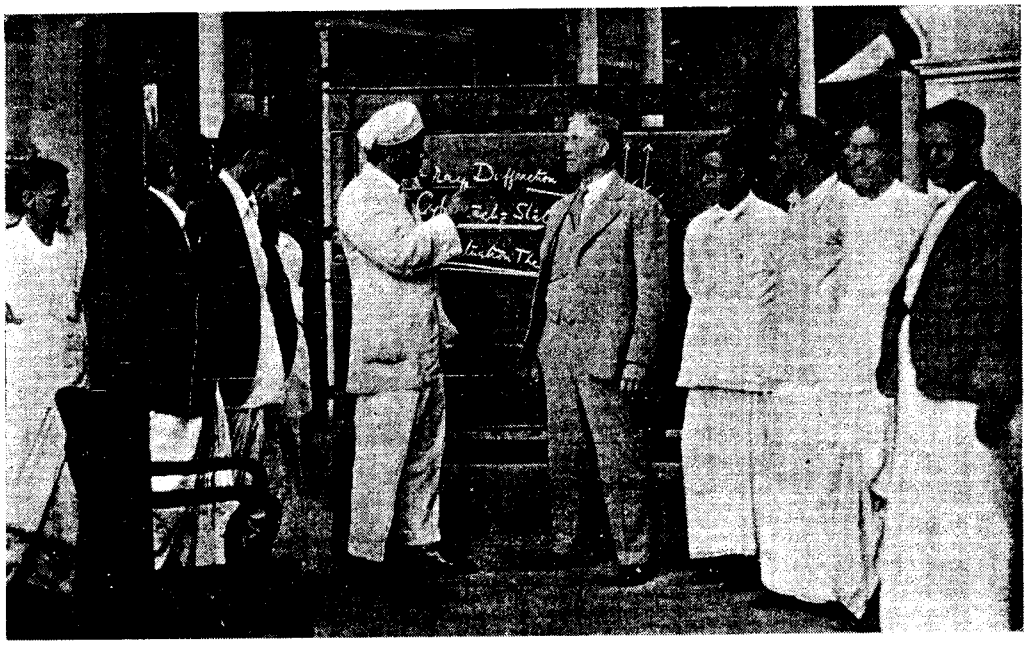
Group photograph of students of the Presidency College, Madras, B.A. Class (1903)
Fourth from the right, in the second row from top, is C. V. Raman

Mr. R. Chandrasekhara Iyer and Parvathi Ammal and their seven children (1906)
C. V. Raman is sitting first from the left.

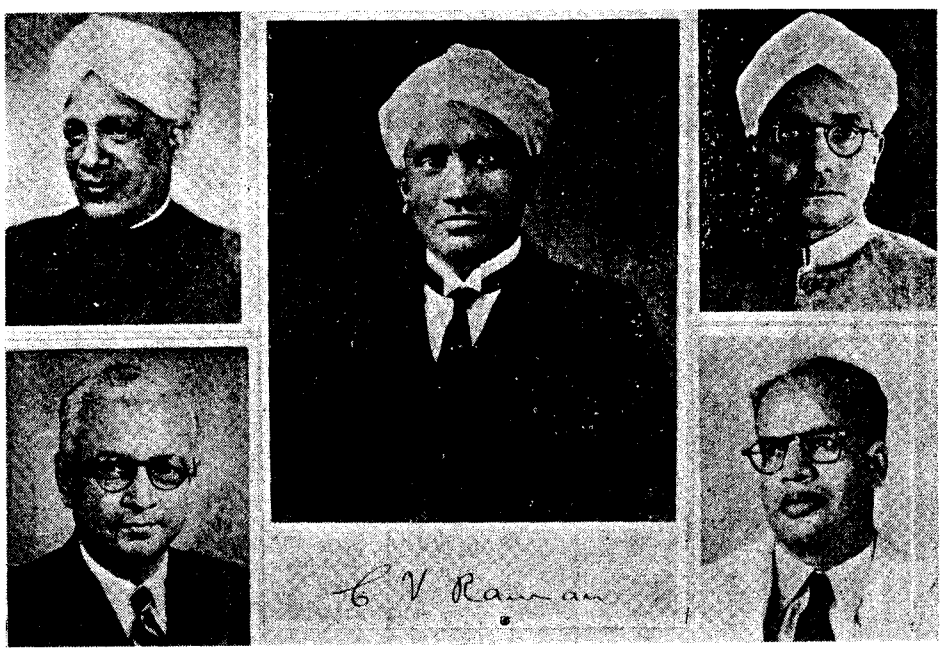
C. V. Raman

Top Row : L to R : Student in Presidency College (1905)
Assistant Accountant General (1909)

Bottom Row : L to R : Professor, Calcutta University (1924)
In informal dress (1931)



Photograph taken after a seminar at the
Indian Association for the Cultivation of Science



Raman and his students

K. R. Ramanathan K. S. Krishnan

C. V. Raman

S. Ramachandra Rao S. Venkateswaran

Raman's Students 1920 — 1928

Top Row : Asutosh Dey, I. Ramakrishna Rao, Durga Das Banerjee

Middle Row : K. S. Krishnan, C. G. Sogani, A. S. Ganesan

Bottom Row : K. Seshagiri Rao, L. A. Ramdas, J. C. Kameswara Rao

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A New Radiation[1]

BY

PROF. C. V. RAMAN, F.R.S.

(Plate XII).

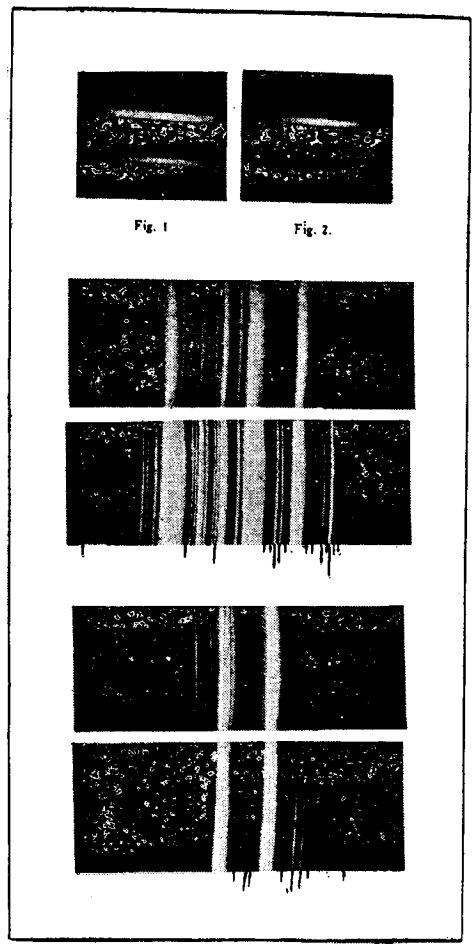
1. *Introduction.*

I propose this evening to speak to you on a new kind of radiation or light-emission from atoms and molecules. To make the significance of the discovery clear, I propose to place before you the history of the investigations made at Calcutta which led up to it. Before doing so, however, a few preliminary remarks regarding radiation from atoms and molecules will not be out of place.

Various ways are known to the physicist by which atoms or molecules may be caused to emit light, as for instance, heating a substance or bombarding it with a stream of electrons. The light thus emitted is usually characteristic of the atoms or molecules and is referred to as *primary* radiation. It is also possible to induce radiation from atoms and molecules by illuminating them strongly. Such light-emission is referred to as *secondary* radiation. The familiar diffusion of light by rough surfaces may be cited as an example of secondary radiation, but strictly speaking, it hardly deserves the name, being an effect occuring at the boundaries between media of different refractive indices and not a true volume-effect in which all the atoms and molecules of the substance

[1] Inaugural Address delivered to the South Indian Science Association on Friday, the 16th March, 1928, at Bangalore.

First page of the paper "A New Radiation" by C. V. Raman
Ind. J. Phys., March 1928



The first Raman Spectra

Plate roproduced from the paper "A New Radiation"

When a photograph was taken of the spectrum using a Hilger Baby quartz spectrograph, the shift in frequency of the new line from the incident one was identified with the change in the energy of the vibrational state of the molecule. Further, modified lines were observed having frequencies both lower and higher than that of the incident light indicating that the incident photon could gain or lose enery when scattered by the molecules.

Story goes that the note to Nature sent by Raman announcing the discovery on March 8th was rejected by a referee but published anyway by the editor.

The following is an extract of the cable to Nature from Prof. R. W. Wood, the distinguished optical physicist of Johns Hopkins University, U.S.A:

"Prof. Raman's brilliant and surprising discovery; I have verified his discovery in every particular. Raman's discovery thus makes it possible to investigate remote infrared regions hitherto little explored.

It appears to me that this very beautiful 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 of light".

Before long many laboratories around the world took up the study of the Raman effect in simple molecules. But in Raman's laboratory the accent was on the study of more fundamental problems connected with the physics of the liquid and solid state using the Raman effect as a tool.

Raman was awarded the Noble Prize for his work "on the diffusion of light and for the discovery of the

effect named after him". His Nobel lecture is a masterpiece of composition relating the exciting story of the persistent efforts from 1921-1930 giving a detailed account of the contribution made by each of his collaborators.

There are two stories that are indicative of the character of this incredible man and his supreme self-confidence. Raman was elected a Fellow of the Royal Society in 1924. At the meeting to felicitate him, he is known to have said – while he appreciated the honour done to him he did not consider it the ultimate and that he would get the Nobel Prize for India within 5 years!

Nobel Prizes are announced in the second or third week of November. The meetings of the Nobel Committee are held in the highest secrecy and the awards are announced in November about a month before the prize giving ceremony in mid-December. It would have been surprising enough that Raman could leave by steam ship after receiving the news by telegram to reach Stockholm in time for the ceremony. It is now a historical fact however that Raman had booked two tickets for himself and his wife in July that year to enable them to reach Stockholm in early December!

In 1933 Raman was offered the Directorship of this Institute, which as you all know was started by that visionary J.N. Tata whose memory is also being honoured today. Raman was at first in two minds about taking it up, but later decided to accept the offer. Before leaving Calcutta he made sure that his brilliant pupil K.S. Krishnan was appointed the Mahendra Lal Sircar Professor at the Indian Association. Regarding Raman's move to Bangalore, Fermor (the Director-General of the Geological Survey) and the President of the Science Congress that year said "At present Calcutta

may be regarded as the centre of scientific research in India. But with the transference to Bangalore of one of the leading investigators, Calcutta will have to guard her laurels".

This was the year many famous scientists were fleeing Germany to escape from the tyranny of Hitler. No sooner had he come to Bangalore then Raman made attempts to get some of them to India. He succeeded in appointing Max Born to an extraordinary chair of physics which he created at the Institute. There is a letter from Schroedinger, the originator of wave mechanics, saying that Raman's offer had arrived a bit too late as he had just accepted an offer from Dublin – regretting that he could not settle in the land of the Upanishads! Ewald, Peierls, Kuhn and many others were also in Raman's list. Years later I once asked him about his attempts to bring these scientists to India. He replied that he had always been against young Indians going abroad to be initiated in scientific research because it would have been done in an environment so completely different from what exists in India. This type of training could have made them useless in our country. If great minds like Born and Schroedinger who were seeking a country to adopt had been provided with a home here, a real scientific movement could perhaps have been started in the country. Unfortunately Raman was prevented in succeeding in this attempt.

In inviting these scientists, he had, characteristically not taken permission of the management of the Institute. For this and other such reasons he was forced to resign from the Directorship of the Institute but he managed to retain his Professorship. I am not familiar with the complete story of this "demotion" but I certainly plan to look into the history of this incident. The formal charges were, in any case, definitely flimsy.

While Raman could admittedly be difficult, one wonders whether it was not just due to the "scientific politics" of that time.

"What is highest is Envy's mark" said Ovid.

In 1934 Raman started the Indian Academy of Sciences and the best young scientists from all over India were elected as Fellows. They began publishing in its journals. It is remarkable that for twenty years right upto 1954 the Proceedings of the Indian Academy was considered among the top journals of the world in physics and chemistry. The annual meetings of the Academy, which Raman used to call his travelling circus, were held in university towns. The most distinguished scientists of the country were always there discoursing and lecturing. But Raman was always the star performer.

I particularly remember the meeting of 1941 in Nagpur where I was a student of the B.Sc.(Hons.) class. K.R. Ramanathan was there, and so was Bhabha. I even remember young Vikram Sarabhai, and there were a host of others. It was a coterie of scientists talking only science. It was so exciting for me and all the young people from the university. Raman, as always, gave the presidential address, and ended the three-day session with a popular lecture. He always drew very large audiences, and this time there were more than 5000 to listen to him. Every man and woman, every boy and girl went back dazed, feeling they had discovered the beauty and the simplicity of science.

During my career I have heard many, many scientists talk and lecture. But Raman in his hey-day was perhaps the best. This opinion, I know, is shared by many of my generation. What was it that made his

lectures so gripping? It was not just his mannerisms or his humour – he made his audiences roar with laughter. To him, giving a lecture was clearing up things in his own mind. He talked of only those things about which he felt intensely, of those things which he understood or wanted to understand. He saw things in their simplest and most basic elements. He made the audience feel that they could have seen it all by themselves (which of course they had not).

He was perhaps the greatest salesman science has ever had in this country. How many gifted young men of the last generation took to science because of having listened to him once?

A word about him and his students. He usually selected very talented young men (and on a few occasions women) to work with him. So powerful was his influence that his students rose to heights which they themselves could not have imagined possible. He was like a conductor who extracted the best music from his orchestra. It was not uncommon that some students who had done extremely well when they were with him, once deprived of his influence were never heard of again!

He used his personal prestige and that of the Indian Academy to encourage scientific talent, wherever it was found and in whatever field it showed itself. From 1924 till about 1954 (when "big science" was established in India) he was one of the main sources of encouragement for scientific talent in the country. In this respect his service to the nation was unique.

As with the Indian Association he made the Physics Department of this Institute a centre of world renown. He worked on such delectable things as the plumage of

birds, the colours of shells, the hues of old iridescent glass, and of soap bubbles. Along with Nagendra Nath, he propounded the now famous Raman-Nath theory of the diffraction of light by ultrasonic waves based on a concept so simple and so elegant. A plane wave of light when it passes through an ultrasonic wave field is speeded up in regions of rarefaction and slowed down in the regions of compression to emerge as a corrugated wave front. This idea cleared the air of many of the theories that were extant and was hailed all over the world. The year after the Raman-Nath papers appeared in the Proceedings, the circulation shot up noticeably.

His school again had a renewed look at the scattering of light by liquids. According to Brillouin, thermodynamic fluctuations in the liquid can be broken up into waves (the Fourier components) which would scatter light with an associated Doppler shift from which the velocity of these waves could be measured. Such measurements were made by Raman's group. But what was more exciting was the discovery that viscous liquids almost behaved like solids at these high frequencies sustaining not only longitudinal but also shear waves. They were able to get the rigidity modulus for these liquids at these high frequencies!

Raman's interest in diamonds is well known. As a direct result of this, his school carried out pioneering studies of the thermo-optic behaviour of solids, their photo-elastic, magneto-optic properties, fluorescence, and second order Raman effect, infrared spectroscopy, etc. It is perhaps not well known that x-ray topography was discovered in this laboratory while studying the imperfection in diamond.

In 1948 he retired from the Indian Institute of Science and was made a National Professor. He had hoped to

start a small institute for himself with his life's savings, where he could retire and enjoy science. But it so happened that he lost most of his savings in a "south sea bubble" investment. He was sixty then and to anyone else it would have been an impossible situation. But Raman was undeterred. He went round the country and collected money.

"Our greatest men were beggars" he said, "The Buddha, Shankara or even Gandhi". He succeeded in collecting enough to start the Institute but not to sustain it.

He then launched courageously on a new project. Advised and aided by an old student, he used what remained of his savings to start a couple of chemical factories, the dividents from which were sufficient to support his Institute and to keep it independent of government grants. Raman was never a member of too many committees, but on his retirement he resigned from every one of them. There is a story concerning his reactions when a feeler was sent out to see whether he would like the Vice-Presidentship of India. He is reported to have had a hearty laugh and asked "What shall I do with it".

For some years there was no equipment or even electrical power in his Institute. He arranged his famous mineral and crystal collection and commenced his researches on the colour and iridescence of minerals and gems. It is remarkable how much information he could extract by just sending a beam of light into a gem and observing the scattering. This led him on to his classical papers on the optics of heterogeneous media.

He took students but this time with greater discrimination, and once more he made his laboratory into a

great centre of research. There were many outstanding research publications from the Institute on the generalised theory of interference, the theory of optical activity in crystals and a variety of other subjects.

It was during this period that he launched upon his researches on the physiology of vision and on floral colours. He was happy surrounded by his exquisite roses, the jacarandas and the bougainvilleas, the hibiscus and the morning glories and enjoyed studying them.

Perhaps the least understood and the most criticised phase of Raman's life was when he suddenly chose to make himself a recluse. He refused to accept even the marginal support he was getting from the Government. Two ministers who visited him once to offer support were told "Why do you want to despoil the only oasis of freedom in the country". He built high walls around the Institute and put up a prominent sign stating that visitors were not welcome. His attitude particularly towards the Government, became one of utmost cynicism.

To those who knew him, he was a soul in agony. He was veritably like Timon of Athens – bitter and cynical.

To Raman, scientific activity was the fulfilment of an inner need. His approach to science was one of passion, curiosity and simplicity. It was an attempt to understand. To him science was based on independent thought, combined with hard work. Science was a personal endeavour, an aesthetic pursuit and above all a joyous experience.

The Indian scientific scene of that time presented to him a very strange picture. The establishment

seemed to believe that scientists cannot be grown in the country as they sent all their bright young students abroad for 'training'. He saw the expenditure of large sums of money – in the belief that science, and therefore technology, will automatically be created. He saw the replacement of quality by quantity. He saw the choice of research topics – dictated mostly by foreign fashions and this hurt him most.

I shall make no value judgement here, but we can imagine what he would have felt. A total negation, in the name of science, of all the values he had lived by. He must have felt that his example had been totally in vain and he blamed the establishment for it.

"My life" he once cried, "has been an utter failure". "I thought I would try to build true science in this country, But all we have is a legion of camp followers of the West".

To my mind the agony of Raman can only be compared to that of Gandhi in Noakhali when he too found that all his life's work was as nought, the apostle of non-violence witnessing his countrymen beating each other to death.

It was in this phase that Raman resigned from the Royal Society of London.

Raman did come out of the slough of despond finally. Almost every day he was seen taking school children and college students round his Institute regaling them with stories and showing them experiments. He began accepting lecture engagements. His charisma was still potent with the younger generation. He attracted enormous audiences, and university halls began overflowing again. He made fervent pleas to the Government to

to improve school and university education and university research.

He said "when we want to achieve – whether it be in science or in anything else we must first learn to use the resources we have in plenty. As a nation what are the resources we have in plenty – human beings of whom at least a third are young. This is our real strength. If they are enthused and if they are instilled with a spirit of adventure, the sleeping giant will wake up and we can conquer the world".

Raman was, of course, the supreme egotist. But in private conversation he often showed such an unbelievable scientific humility as to make one wonder which was his true self. He always told people what he felt and in this process hurt many. He was a man of emotion and he could get violently angry. Some of us still remember, how he wept like a child during one of the Academy lectures when pictures were shown of children of our land suffering from nutritional ailments. He had an incredible sense of humour and he could keep us roaring with laughter just describing what could have been commonplace incident.

He was a very simple man, quite childlike – sometimes even childish.

The science administrators of today would even think him naive. For example he believed that the only method of promoting science was by doing it, and to him the professional organisers of science were an abomination. "For such people" he said "the so-called organisation of science becomes more important than science itself or its values".

To him the simplest observations that he could make by just looking around him were worthy of the

deepest scientific investigation. He demonstrated over and over again that a deeper understanding of these every day phenomena paved the way for the discovery of fundamental laws. He relied greatly on intuition – in fact Max Born once said "Raman's quick mind leaps over mathematics".

Anyone who met him could not but be struck by his zest for life. Born refers to this in his letter to Lord Rutherford written in the later half of the thirties. Born says "there is no Indian physicist of the rank of Raman. No man can compare with him regard to vigour or intensity. This European intensity which Raman exhibits to a marked degree would make any average Indian scientist suspicious of him".

His exhuberance was infectious. Chatting with him for some time was like taking a tonic.

To those of us, who knew him well, what struck us most was his intense love of and preoccupation with nature – the colours of birds, the sheen of the beetles, the blue of the sky, the spectacular hues of the coronas and the glories that surround the Sun and the Moon, the extraordinary beauty of minerals, crystals and gems – not only thrilled him but formed the subject matter of his scientific studies.

A few months before he died, I remember, while walking with him one evening amongst the eucalyptus groves that he loved, he stopped me in his characteristic manner and pointing towards the sky said: "Have you seen anything so beautiful?"

Above, one saw little wisps of multi-coloured clouds passing close to the Moon, which gleamed over the shimmering leaves of the trees – trees which appeared like nature's own cathedral.

"This is happiness" he said. "That we should be alive, and that we should be endowed by nature the faculty to perceive this fleeting vision of beauty — this is happiness indeed".

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