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# A DANCING WU LI MASTER

By A. Ranganathan

IN his autobiographical work entitled 'A Mathematicians's Apology' (Cambridge University Press, 1941), the renowned English mathematician, Prof G.H. Hardy, observed that "a mathematician, like a painter or a poet, is a maker of patterns... The mathematician's patterns, like the painter's or the poet's must be beautiful; the ideas like the colours or the words must fit together in a harmonious way".

Indeed, Prof C.V. Raman, the first Asian scientist to win the Nobel Prize for his contributions to Physics in 1930, was inspired by this quest for beauty in his scientific career. And Prof Raman's scientific investigations on the colour of the Mediterranean Sea and of ice in Canadian glaciers, the physics of the Radiant Spectra, the origin of colours in the plumage of birds and iridescent shells, the Whispering Gallery Phenomenon of St. Paul's Cathedral, the physiology of vision and of hearing, the structure of the diamond and the physical theory of musical instruments can be perceived as a symphony of light, colour and form, sound, harmony and rhythm.

Chandrasekhara Venkata Raman was born on November 7, 1888, at Tiruvanaikaval, near Tiruchirapalli in the old Madras Presidency. He had his early education at Vizag, where his father was a lecturer in Physics at Mrs A.V.N. College. In fact, his educational background was truly remarkable. For it included a study of Charles Lamb's 'Tales from Shakespeare' and the works of Shakespeare, Milton and the Romantic poets, the popular works of Tyndall and Helmholtz as well as scientific works such as Ewing's 'Magnetic Induction in Iron and other Metals' and Helmholtz's 'Sensations of Tone'. Professor S. Ramaseshan, President of the Indian Academy of Sciences, has said in a recent essay that Raman read two popular works — 'New Fragments' by John Tyndall and 'Popular Scientific Subjects' by Hermann von Helmholtz — when he was between 11 and 13. Here, indeed, was a product of "the two cultures — scientific and literary" in the C.P. Snow sense of the term.

As a young student, Raman was particularly fascinated by 'The Elements of Euclid'. The study of geometry made a profound impact on his senses and intellect. "The pages of Euclid" constituted "the opening bars of music in the grand opera of Nature's great drama" he had remarked. Later, he joined Presidency College in Madras, where he came under the influence of Prof Jones, who revealed the aesthetic value of scientific study.

Raman had a brilliant academic career. He took a B.A. degree in December 1904, winning the highest academic distinctions and the Gold Medal in Physics, besides receiving the Lord Elphinstone Prize for his essay on "Indian Epic Poetry". In the M.A. examination in January 1907, Raman secured a first class and created a record in the history of Madras University. His earliest experiments in both optics and acoustics were conducted while he was still a student. In 1906 appeared his first scientific paper on Diffraction Bands of Light, a subject he was to make peculiarly his own later on in his career.

Raman had also recorded that Helmholtz's work on 'The Sensations of Tone' influenced his intellectual outlook and laid the foundations of his future work in acoustics. However, as he was not able to visualise the "possibility of a scientific career" he sat for the competitive examination then known as the Financial Civil Service and secured first place. This led to his appointment as an Assistant Accountant-General in Calcutta in June 1907. Although the next 10 years of Raman's life were spent as an officer of the Indian Finance Department, he utilized his leisure to conduct research on the physical theory of musical instruments in the laboratory of the Indian Association for the Cultivation of Science.

His work on the Physical Theory of Musical Instruments resulted in two fortunate circumstances. First, Sir Asutosh Mookerjee — celebrated as a brilliant mathematician, Vice-Chancellor of modern India's prestigious Calcutta University and Judge of the Calcutta High Court — invited Raman to enter academic life as the first Palit Professor of Physics at Calcutta University. Second, Raman's monograph on 'The Physical Theory of Musical Instruments' was published in the 'Handbuch der Physik', 1927 (the German encyclopaedia of contemporary physics). Incidentally, this invited paper was published by the German Physical Society at a time (during the twenties) when the Germans dominated the world of physics.

The study of colour always had a fascination for Professor Raman. During a sea voyage to Europe in 1921, he observed "the wonderful blue opalescence of the Mediterranean Sea" and subsequently also perceived the greenish blue colour of ice in Canadian glaciers. While noting a glacier in the Rocky Mountains, it struck Prof Raman that the colour was due to the selective scattering of the blue end of the Solar Spectrum where light traverses a mass of ice.

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Moreover, while studying the famous Whispering Gallery Phenomenon of St. Paul's Cathedral in London in 1921, he was led on to the verification and continuation of his earlier optical analogue experiments through the process of simulating this phenomenon optically. This enabled Raman to demonstrate that the luminescence of a pearl was similar in the sense that light got reflected around the surface of the pearl just as sound (according to the Rayleigh explanation) is reflected around the corners of a whispering gallery and thus carried.

Seen with the vantage of hindsight, Raman's sea voyage to Europe in 1921 marked the first stage in the discovery of the 'Raman Effect'. Here, it may be recalled that in his Nobel Lecture, Prof. Raman observed: "In the history of science we often find that the study of some natural phenomenon has been the starting point of a new branch of knowledge". Indeed, in 1899, Lord Rayleigh had calculated the number of molecules in a unit of volume in air while enjoying the scenery of Mount Everest from the terrace of his hotel in Darjeeling. Again, while viewing the dimness of the mountain's outline, he rightly concluded that an appreciable part of its light was scattered away. And while reflecting on the Rayleigh thesis that the blue light of the sky is the result of the scattering of sunlight by the gases of the atmosphere, it is well to remember the brilliant explanation of Leonardo da Vinci who noticed that the sky became much darker while scaling the Alpine peak of Monte Rosa in 1498. However, the validity of the subsequent Rayleigh theory that "the much-admired dark blue of the deep sea... is simply the blue of the sky seen by reflection" was questioned by Raman while voyaging through the Mediterranean and Red Seas in 1921.

In the wake of quenching the surface-reflection of the sky in the sea through a polarising Nicol Prism at the Brewsterian angle, Raman observed that the colour of the sea was not only impoverished but actually spectacularly improved. It was clear, therefore, that the blue opalescence of the Mediterranean Sea was due to the scattering of sunlight by the molecules of water. The visual impact of the blue of the Mediterranean Sea on Raman resulted in his celebrated paper on 'the Molecular Scattering of Light in Water and the Colour of the Sea.' This paper, which was published in the Proceedings of the Royal Society of London in 1922, not only led Prof. Raman to the discovery named after him but is also as much a fundamental contribution to optics as it is to aesthetics. For the Raman paper on the deep blue colour of the Mediterranean Sea recalls that aesthetic sensibility which can still be experienced while reading through Galileo Galilei's 'Starry Messenger' as well as unveiling poetic vistas of a famous line in Byron's 'Childe Harold's Pilgrimage': Roll on, thou deep and dark blue ocean, roll!"

Raman's publication, 'The Molecular Diffraction of Light' (1922), marked the second stage in the discovery of the 'Raman Effect'. For he was convinced that the quantum nature of light should reveal itself in Molecular Scattering. Indeed, according to Prof. S. Ramaseshan, "Prof. Max Born had told Prof. N.S. Nagendra Nath that he was impressed with Raman's strong advocacy of the light quantum in 1921, that he was very pleasantly surprised at Raman's grasping the basic theoretical implications of the Kramers-Heisenberg process, but was truly astounded by Raman's insight in 1921 that Maxwell's field equations would have to be modified to suit the Quantum Theory".

The final stage in the discovery began with the investigation of the sunlight scattered by a number of liquids. Any by using light of a single frequency from a mercury arc, Raman discovered that the new frequencies in the scattered radiation were characteristic of the scattering medium. In other words, the "Raman Effect" may be described as the scattering of light from a solid, liquid or gas with a shift in wavelength from that of the usually monochromatic incident radiation. This great discovery announced on February 29, 1928 (modestly described as a new type of Secondary Radiation by Professor Raman and happily christened as the 'Raman Effect' by the famous German physicist, Peter Pringsheim of Berlin University) won international recognition for him, including the Matteucci Medal of the Italian Academy of Sciences in 1928, a Knighthood in 1929, the Hughes Medal of the Royal Society in 1930, the Nobel Physics Prize in 1930 and the Franklin Medal of the Franklin Institute, Philadelphia in 1941.

The 'Raman Effect' was not only a brilliant experimental confirmation of the new physics based on the Quantum Theory, but also an effective tool in the study of the structural problems of chemistry. Again, it was fortunate that Prof. Raman lived long enough to witness a renaissance in the entire field of Raman Spectroscopy owing to the use of lasers which constitute scientifically ideal and aesthetically satisfying sources for observing the 'Raman Effect'. Not surprisingly, nearly 45,000 papers have so far been published on various aspects of Raman Spectroscopy and Laser-Raman Spectroscopy. Moreover, the number of papers appearing annually in recent years is well over 3,000. Indeed, even Prof. Raman would not have dreamt of the new renaissance in spectroscopy that we are witnessing today.

The new discipline of Laser Raman Spectroscopy, which has replaced the original techniques of Raman Spectroscopy, has contributed to the new renaissance in spectroscopy, as a result of the light emitted by the Laser Beam that is characterized by a pure frequency and high directionality. Moreover, the laser beam is not merely an indispensable tool of the technologist, but has proved effective in the experimental verification of physical theories. For instance, Raman and Prof. N.S. Nagendra Nath had formulated a mathematically elegant theory concerning the behaviour of ultrasonic waves during the mid-thirties (1935-36), which made Professor Max Born excitedly affirm that "Raman's quick mind leaps over mathematics". And this Raman-Nath theory was experimentally confirmed by a group of scientists at the Columbia Radiation Laboratory in February 1963.

When Raman died of heart failure in Bangalore on November 21, 1970, India lost a great scientist whose work straddled physics and physiology. Indeed, in his address to the World Genetics Congress in December 1983, the Nobel Laureate, Dr Hargobind Khorana, remarked that the new research on the "Proton Pump" of the purple membrane operated by Vitamin A, could enlarge the scope of Raman's initial work on the visual processes.

Raman was a poet among physicists. Shelley, had he gone on with physics, and had he lived in the days of exact measurements, might have shared in Raman's work. Alexander Pope's epitaph, intended for Sir Isaac Newton, is well-known:

"Nature and Nature's laws
lay hid in Night.
God said, Let Newton be!
and all was Light".

Perhaps one could compose a similar epitaph for Raman:

Newton's Spectrum and Light's
Scattering lay hid in
The Mediterranean opalescence.
God said, Let Raman be!
and all was Laser-Raman
luminiscence.