

Ganesan Venkataraman: an admirable teacher, meticulous scientist and a visionary

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Ganesan Venkataraman, GV, as we fondly address him, has contributed so immensely in the past six decades to various fields – scientific, technical, intellectual, managerial and, in recent years, the spiritual side of life – that it would be hard to find another parallel, in depth and diversity, anywhere close to him. GV's commitment to every task that he has ever undertaken in his long career has the fragrance of missionary zeal, because he has always strived hard to achieve perfection in all his pursuits. One cannot do justice to his personality by writing a few pages. The best I can do here is to give the reader a brief insight into his life, touching upon his evolution over the years and sharing my own knowledge of him or that garnered from others. In his glorious innings of 60 years, I was fortunate to have an association with him for over 50 years, starting from 1965.

GV's scientific career began in mid 1955 when he joined the Atomic Energy Establishment Trombay (AEET), Bombay (now Mumbai) and where he stayed till the end of 1973. (In 1967, AEET was renamed Bhabha Atomic Research Centre (BARC) by the then Prime Minister late Indira Gandhi, after the demise of Homi J. Bhabha in an air crash in January 1966.) During his stay in AEET, GV mostly worked in the fields of neutron scattering and dynamics of solids and liquids. In December 1973, he left AEET and joined Reactor Research Centre (RRC), Kalpakkam, Tamil Nadu under the Department of Atomic Energy (DAE). In the golden period of our close association before he left for Kalpakkam, we worked together on many scientific problems, and also embarked on the indigenous development of a state-of-the-art equipment for laser-based Raman scattering studies, as will be described later in this article.

After moving to Kalpakkam, there was a huge increase in the range of his scientific activities. I learnt from him about his starting a comprehensive materials science programme focusing on experimental techniques to help unravel radiation damage in materials, his initiatives

to set up the computer centre, library and also to begin a well-structured instrumentation programme. In late 1987, he left DAE to join the Defence Research and Development Organization (DRDO), to set up a new laboratory in Hyderabad. Even decades later, a visitor to any of institutions can vividly see that GV's contributions remain as an inspiration for others to follow. He has not only nurtured the careers of many scientists and engineers, but is in touch with many of them till this day.

In the early 1990s, after his 'formal' retirement from DRDO in 1992, GV moved to Prasanthi Nilayam and took up duties as the Vice Chancellor of Sathya Sai Institute of Higher Learning, and thus his association with Sri Sathya Sai Baba began. It was then that he unleashed his creativity towards uncovering the spiritual side of life, besides being involved in scientific pursuits with deep philosophical implications.

For his long and distinguished contributions to Indian science and technology (S&T) programmes, many honours have been bestowed on GV including Padma Shri by the Government of India; Fellowships of the Indian Academy of Sciences (IASc), Bengaluru and the Indian National Science Academy (INSA), New Delhi; Jawaharlal Nehru Fellowship; Fellowship of the Materials Research Society of India; Sir C. V. Raman Award of the University Grants Commission, and also the Indira Gandhi Prize for Science Popularization by INSA. Clearly, GV is a remarkable man, not only because he has navigated a variety of programmes across many institutions in the country, but more because, whatever and wherever he started an activity, it invariably carried his imprint long after he had moved on. His exceptional gift to take up a totally unfamiliar subject and in a short time figure out its central issues and then articulate them with consummate ease has made GV an amazingly self-taught man. During the course of his long career, even as he has intellectually enriched himself, GV has all along radiated his knowledge via his lectures and books. His formidable intellectual strength is

not easy to describe, because to do full justice to that task, would really need another GV.

Early life and scientific activities at AEET/BARC, Mumbai

GV was born on 6 October 1932. His father, worked for India Meteorological Department (IMD) and was posted in different parts of the undivided India. That included far-flung places like Karachi (now in Pakistan), where he lived for about 10 years before being transferred to Madras in 1945–46 just ahead of the partition of the country. So, during childhood and adolescent years, GV witnessed many tumultuous events, like the World War II which started when he was barely seven years old, the Quit India Movement in 1942 and Indian independence in August 1947. During World War II, as a safety measure, GV's father decided to shift his family (wife, son and a daughter) from Karachi to a village near Madurai, where GV's grandmother lived. It was then that young GV saw at first-hand the impoverished conditions of villagers living in rural India. This left a lasting impression on him and explains to this day his natural soft corner for rural India.

Due to events just described and enforced shifting from one city to another, GV's schooling got considerably disturbed. So, he not only studied at home, but also attended different schools, including Annie Besant School in 1946–47, and Ramakrishna Mission Residential School in 1947–1949, both located in the then Madras city (now Chennai), before he began his college education in 1949. From 1949 to 1954, he studied at the Madras Christian College (MCC) for his Intermediate Course and B Sc Honours degree in physics. MCC was a reputed college at that time and would give even its B Sc students a taste of research. It had trained outstanding students like the famous physicist George Sudarshan (who was three years senior to GV) and many others. Growing up in that environment, while

still a student, GV volunteered to assist Bernard Peters in cosmic ray research through balloon flights. Although this kindled his research interests in physics, after earning his B Sc Honours degree in 1954, GV was ready to try a career in engineering and joined the Electrical Technology (ET) Department at the Indian Institute of Science (IISc), Bengaluru. (In those days, IISc offered three year 'Diploma' courses in three disciplines, ET being one of them. But only B Sc degree holders were admitted to such courses.) However, as engineering did not excite him, GV toyed with the thought of joining the group of G. N. Ramachandran, who was already a celebrated crystallographer of the time. Luckily, GV's father saw a newspaper advertisement about openings in Tata Institute of Fundamental Research (TIFR)/AEET in 1955, and forwarded it to his son, who promptly sent in his application. This was a turning point in GV's career. For he left the engineering course at IISc and headed in a different direction, and as described below, it proved gainful for Indian scientific institutions, especially, for DAE and DRDO.

Here let us recall that while the Atomic Energy Commission (AEC) was formed by the Government of India in 1948 (soon after independence) with Homi Bhabha (then Director, TIFR) as Chairman, the activities of DAE were constrained due to limited space then available at the Old Yacht Club building in South Bombay that housed all the scientific programmes. The situation completely changed when Bhabha got a large campus space allocated at Trombay (on the northeastern side of Bombay of that time) to begin the AEET laboratories in 1954, on a much larger scale. So, for GV, it was a blessing that he applied at a time that was coincident with Bhabha's envisioned expansion of the DAE activities. After an interview he got selected and was assigned to a team headed by Raja Ramanna, who had earlier returned from the UK with a doctoral degree to join TIFR in 1949. Then in 1954, on Bhabha's suggestion, Ramanna agreed to also supervise nuclear physics-related activities in AEET. After his selection, as the issue of GV's job offer involved some paper work and was to take time, he sought and was allowed to join work, even before the job offer was issued to him. I learnt that for over two months,

until he received the offer letter, he worked without any remuneration from AEET.

When GV started his scientific career in 1955, there was enormous emphasis in AEET on building scientific equipment for one's research work indigenously. He too built electronic units such as discriminator, pulse counter, amplifier, pulse height analyser, etc. This was a boon, because when APSARA (AEET's first research reactor) became critical in August 1956 and began offering neutrons for experimental work, GV was well poised to use the reactor right from the word 'go'. With a decent start in neutron beam research at Trombay, GV got opportunity to work at Chalk River Laboratories, Canada, which was then the 'Mecca' for neutron scattering research. In 1957, he went to the Atomic Energy of Canada Limited (AECL) for a 15-month period and interacted with Bertram Brockhouse (who later shared the 1994 Nobel Prize in Physics for his neu-

tron scattering work) and others. Peter Egelstaff (a visitor there from Atomic Energy Research Establishment, Harwell, UK), a leader in the use of neutrons to study liquids got GV interested in the time-of-flight technique. After he returned from AECL, AEET's second nuclear reactor, the Canada India Reactor (CIR) attained criticality in July 1960, giving a boost to neutron scattering research activities at Trombay. Using his AECL experience, GV along with Usha Deniz built a time-of-flight machine (rotating crystal spectrometer, RCS) and installed it in CIR. Its schematic and a photograph are shown in Figure 1. Shielding hides the details of the schematic in the actual picture. RCS was used for studying a variety of problems in condensed matter physics.

By 1964, scientific reputation of the neutron scattering group at Trombay was well established in the international community, resulting in the International Atomic Energy Agency (IAEA) deciding

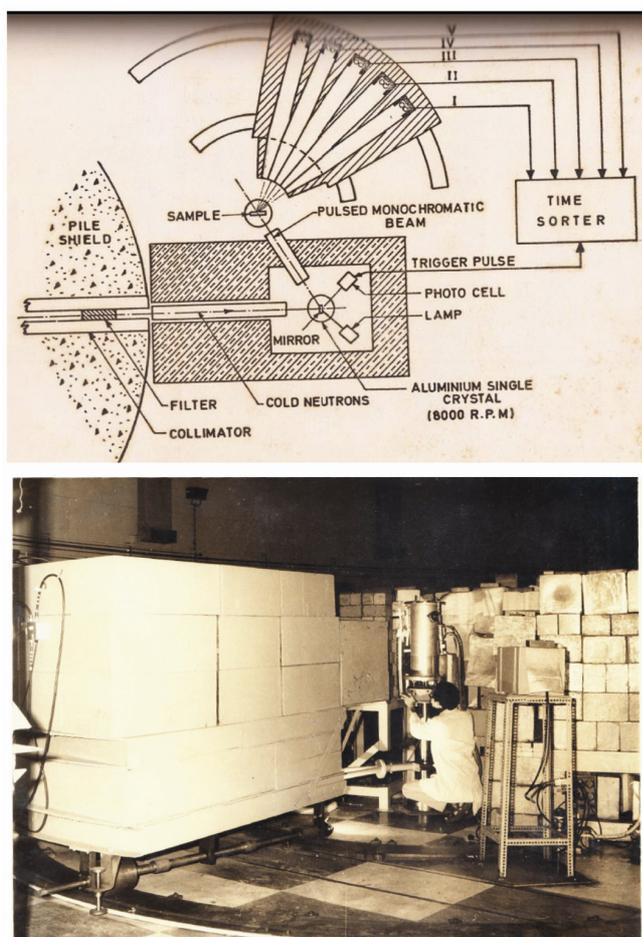


Figure 1. A schematic of rotating crystal spectrometer (top) and a photograph of the machine built by GV and Usha Deniz (bottom).

to hold its Inelastic Neutron Scattering Conference at Bombay in December 1964. The conference brought GV into close contact with many of his international peers and from then on, he began to be counted amongst top experts in the world in the area of neutron scattering. One of his contacts resulting from the conference was Sunil K. Sinha, who later received the 1996 Lawrence Award for his contributions in the field of neutron scattering and also received the 2014 Clifford Shull Prize for neutron science given by the Neutron Scattering Society of America. After the conference, Sinha stayed on at AEET till September 1965 (before he joined Iowa State University, USA), and along with GV, built the foundation of a strong collaboration. This resulted in their pursuing many contemporary problems in solid-state physics, including first principles calculation of phonon dispersion curves in metals, an area in which I was associated with GV in the early part of my scientific career. To this day, Sinha maintains his contact with GV and addresses him as ‘Sir GV’. (This was long before GV wrote the famous scientific biography of Sir C. V. Raman, *Journey into Light*, which was released in 1988 during Raman’s birth centenary celebrations.) Sinha and GV have been life-long friends and always eager to discuss contemporary scientific problems.

From early 1960s till GV’s departure from Trombay in 1973, most of the neutron beam research grew around the CIR reactor. While late P. K. Iyenger led the whole programme, separate research teams ran their own focused activities under their group leaders. GV was group leader for the inelastic neutron scattering studies; neutron diffraction was supervised by R. Chidambaram and magnetic studies by N. S. Satya Murthy. There were, of course, established scientists in each group. Amongst GV’s prominent colleagues I must mention, K. Usha Deniz, B. A. Dasannacharya, late K. R. Rao, late C. L. Thaper, R. Subramanian, A. P. Roy, late Raju N. Aiyer and P. R. Vijayaraghavan. Their main tools were triple-axis spectrometer, multi-arm spectrometer filter detector spectrometer and rotating crystal spectrometer. Though I may not be able to give details of the various studies that GV and his team conducted over time, I must mention that data collection in the inelastic neutron scattering experiments used to be slow

and it took several months to a year or more to fully study a sample. Notable studies done by the team, included measurement of the phonon dispersion curves in hexagonal metals – beryllium, magnesium and zinc. The measurements in beryllium were particularly tough due to high phonon frequencies. The team also investigated Kohn anomalies in zinc; measured phonons in complex molecular ionic crystals and studied molecular rotation in ammonium salts using the time-of-flight technique and filter detector spectrometer. Other areas of studies by GV’s team included anharmonicity in the librational modes in molecular systems and molecular reorientation in crystals through quasi elastic neutron scattering. The pair correlation function measurements in liquids were also investigated using neutron diffraction. The research earned many persons their Ph D degrees.

My own first contact with GV happened while I was a ‘physics trainee’ in the AEET Training School during 1964–65. He taught us a short course on lattice dynamics, and was clearly in a different class compared to all other teachers we had come across. GV was sharp and crystal clear in his lectures, but he equally expected all of us to measure up to his stiff yardstick. When the training course ended in July 1965, the Nuclear Physics Division (to which GV belonged) was going to induct several physics graduates from our batch. Since I had topped my batch, I got a choice to work with GV to start a life-long association. Here I must recall an incident soon after I joined duty. On the third day, GV called me out of the room (where over a dozen of us used to sit) and as usual when I addressed him as ‘Sir’, he cryptically said ‘Stop Sir-ing’ ‘You are no longer in the Training School’. When I asked him ‘But how do I address you?’, his reply was straight: ‘I suppose you know my name’. I recall this story only to emphasize that to GV’s mind such ‘bureaucratic afflictions’ had no place in a scientific institution. Later, I found that there were hardly any other parallels of GV even in AEET at the time. Sadly, that ‘Sir-ing affliction’ which GV despised, still survives in our institutions.

From August 1965 till December 1973 (when GV moved to Kalpakkam), we worked on a number of problems that included first principles calculation of phonon dispersion curves in beryllium; use of the group theoretical methods to

classify elementary excitations in solids such as phonons in simple and complex crystals, polaritons, magnons, etc. and developed a method to construct irreducible multiplier representations of crystallographic point groups. A portion of this work formed part of my Ph D thesis submitted to Bombay University with GV as my de-facto guide. We also wrote review articles which appeared in *Reviews of Modern Physics (RMP)* in 1970 and *Advances in Physics* in 1974. Our *RMP* article gets cited even now; it has the distinction that it was the second paper to be published in *RMP* by DAE staff members, the first one being by Bhabha himself. After it had appeared in print, G. S. Pawley from Edinburgh wrote to GV that considering the comprehensive nature of our article, he had shelved writing a book on the external vibrations in complex crystals and may be five years later, when lot more data are available, he might return to the book-writing project. Similarly, while visiting USA, Ramanna met S. Chandrashekar in the University of Chicago and asked him if he had read our article. I learnt from a friend present there that Chandrashekar had not only read the paper, but also told Ramanna, ‘it is an extremely well written article’. As my friend told me, those words from Chandrashekar certainly pleased Ramanna. Besides these articles, we also collaborated and wrote a monograph titled *Dynamics of Perfect Crystals* published by MIT Press, USA. It was co-authored with Lee A. Feldkamp, who was associated with GV (during the latter’s sabbatical at the University of Michigan, Ann Arbor, USA) in 1967–68. While the manuscript was nearly finished before his departure for Kalpakkam, towards the end of this project (when the editorial changes had to be incorporated and proof reading, etc. had to be done), GV, Feldkamp and I were located in different cities and handled everything through classical postal mails! The book finally appeared in print in 1975 and got excellent reviews, with a reviewer in *J. Opt. Soc. Am.* describing it as ‘a worthy successor to *Dynamical Theory of Crystal Lattices* by Born and Huang’. It may be noted that this book by Nobel laureate Max Born and his associate Kun Huang was published in 1954 and was regarded as the last word on the subject. In several ways it was remarkable because, despite a manifold increase in responsibilities before his moving to Kalpakkam, GV

invariably was ahead of both Feldkamp and me.

Before I turn to a narration of GV's post-1973 scientific activities at Kalpakkam, let me mention a few aspects that I found unique to his personality. While his areas of research were neutron scattering and lattice dynamics, GV was equally proficient in the fields like magnetism, crystallography, etc. His far wider perspective amongst his peers in AEET and TIFR at that time, was exceptional. I recall a 1966 lecture on elementary particles that he gave in the CIR lecture hall (as a part of an 'Anti-obsolescence' series started by Chidambaram), wherein he gave a fascinating and comprehensive account of the subject. His guideline to anyone giving a lecture at that time (and which he himself followed to the core) was this: 'Imagine you have the smartest of the audience asking you sharpest of the questions.' 'You should have thought of all those questions in advance, so that you are on top.' He also paid great attention to making good transparencies and slides. Thus listening to his lectures was always a treat, as he could put across difficult ideas in a simple way for anyone to understand. Over time, GV also expanded the scope of his own research interests. That is how he added Raman scattering and Brillouin scattering (as supplement to neutron scattering), study of liquids, magnetic materials, as well as infrared and dielectric measurement techniques, etc. into his areas of study. GV was the major force behind our indigenously built double grating laser Raman spectrometer that was completed soon after he moved to Kalpakkam and has been functioning ever since with many upgrades.

After returning from USA in 1968, GV started 'Graduate courses' in BARC to strengthen the foundations of younger colleagues. He was also the principal architect of the uniquely interactive 'Refresher courses' that BARC used to conduct for physics teachers working in various universities and colleges in the country. Through all these efforts, GV greatly enriched the academic ambience in BARC, especially in the Physics Group, and when Sinha spent a year again at Trombay in 1972-73 (on sabbatical from Iowa State University, before GV moved to Kalpakkam) such activities were even further intensified. A memorable photograph taken at that time in the Modular laboratory of BARC with

GV, Sinha and many other colleagues is shown in Figure 2.

Although GV left for Kalpakkam soon after work on building the 100 MW high-flux reactor Dhruva began, the stimulating culture in neutron scattering that he had created enabled his colleagues to carry forward the plan to build high-quality facilities around the reactor. Over the next two decades, a variety of neutron instruments were built and neutron guides were established to enhance the range and reach of the programme and provide access to users across the country. Key role in this effort was played by late Rao, late Satya Murthy, Vijayaraghavan, A. S. Sequeira and L. Madhav Rao. S. K. Paranjape, late Thaper, P. S. Goyal, R. Chakravarthy, J. N. Soni and Y. D. Dande rendered valuable support, while late Iyengar was the sheet anchor for the whole programme. Due to their efforts and the facilities they built, a national programme on neutron beam research got underway in the late 1980s. With this, the entire scientific community in the country could access the neutron scattering facilities around Dhruva reactor. This arrangement continues to flourish even now. (Readers interested in details of the early instrument developmental activities in neutron beam research can refer to the *Indian Journal of Pure and Applied Physics*, 1989, 27.) These and many other new facilities added later have served as the bedrock of a resurgent neutron scattering programme at Trombay. Four widely attended international conferences were hosted by BARC during 1991-2013, with GV always being in the midst in all meetings, except one.



Figure 2. (Left to right): K. R. P. M. Rao, J. N. Soni, A. S. Sequeira, L. Madhav Rao, R. Subramanian, T. Ramanujam, G. Venkataraman, N. S. Satya Murthy, C. Manohar, Virendra Singh, Akalpita Paranjape, R. J. Begum, Vinod C. Sahni, R. Chidambaram, Sunil K. Sinha, C. S. Somanathan, Usha K. Deniz, K. R. Rao, A. P. Roy, B. A. Dasanacharya, T. Srinivasan, V. C. Rakhecha, C. L. Thaper and P. R. Vijayaraghavan.

When GV was relocating to RRC (later renamed as the Indira Gandhi Centre for Atomic Research (IGCAR) in 1985 by the then Prime Minister late Rajiv Gandhi), he entrusted me the task of going through his files. His instructions were that I dispatch reprints of papers that he would need (since the library at RRC at that time was still in its infancy and not well-equipped) and his important correspondence, and discard the rest. It was in the course of fulfilling those instructions that I came across some of GV's hand-written notes. As these were not to be dispatched to Kalpakkam, I had the liberty to handle them as I wished. But a quick glance at those papers convinced me that I must retain them in view of the care and attention embedded in those hand-written notes. Over time, I have lost a few, but some are still with me, like notes on 'Techniques to study band structure of semiconductors', 'Electronic structure and Fermi surface', etc. (prepared very early by GV in his career) which reveal that his outstanding abilities as a communicator were acquired through a lot of hard work. Today, when the practice of writing in long hand has practically disappeared, GV's notes (see the extract displayed in Figure 3) can still serve as a powerful stimulus.

New responsibilities as principal physicist at RRC, Kalpakkam

In a way, while his departure from Trombay was a setback to physics activities at BARC, it was a big gain for RRC. When

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he moved to the Centre in December 1973, GV was designated as the Principal Physicist in RRC. He launched a comprehensive Materials Science Programme, built the computer centre and library facilities and also embarked on the task to plan and start the Electronics and Instrumentation programme at RRC. Later he was designated as the Director, Physics, Electronic and Instrumentation Group in RRC. Recognizing that the primary mandate of RRC was to build a S&T base for fast reactors in the country, GV reckoned that fast-neutron induced damage in materials had to be studied in depth, since it was going to play a crucial role in every facet of the design, operation and maintenance of such reactors. He decided to follow a multi-pronged strategy. It involved (a) setting up experimental facilities to induce damage in the materials of interest and preserving the damage through cryogenic techniques (including use of liquid helium); (b) investigating the induced damage using a variety of physical techniques that encompassed macroscopic properties, including internal friction and related studies, as well as looking at a material microstructurally using techniques like XRD, perturbed angular correlation, positron annihilation, Mossbauer effect, SEM, etc., besides doing high-pressure dependent studies; (c) developing a theoretical basis to understand and get an insight into the 'whys' and 'hows' of the damage, and (d) doing computer simulation to build models to eventually benefit the teams working on fast reactors.

Since physicists at that time had recognized that energetic charged particles (with tens of mega electronvolt energy) could be used to mimic fast neutron-induced damage in a material, GV had visualized a tie-up with the Variable Energy Cyclotron Centre (VECC) in Calcutta (now Kolkata) and envisaged building a lower energy (tandem) accelerator for in-house use by the RRC scientists and engineers. He carefully planned many other facilities; I will not go into details, except to mention that the culture he created in those areas can be felt even today if one visits IGCAR.

Besides embarking on the creation of the physical infrastructure, GV did his best to usher in a cultural change in the way people thought and worked in RRC. He encouraged others and also pioneered in delivering lectures on contemporary topics (like fusion research) and then

bringing out the lectures in the form of RRC reports. He was keen to create a vibrant and open academic environment in RRC, where scientists and engineers partner among themselves and also team up with their peers in other institutions (Figures 4 and 5). I recall his plans for a tie-up with the Atomic Fuels Division of

BARC in the 1970s to develop Nb-Ti/Cu multi-filament superconducting wires. Clearly, he was far ahead of others in conceptualizing such programmes. In fact, the way he systematized information storage and retrieval system and introduced computerization at RRC long before others in the country did, shows his

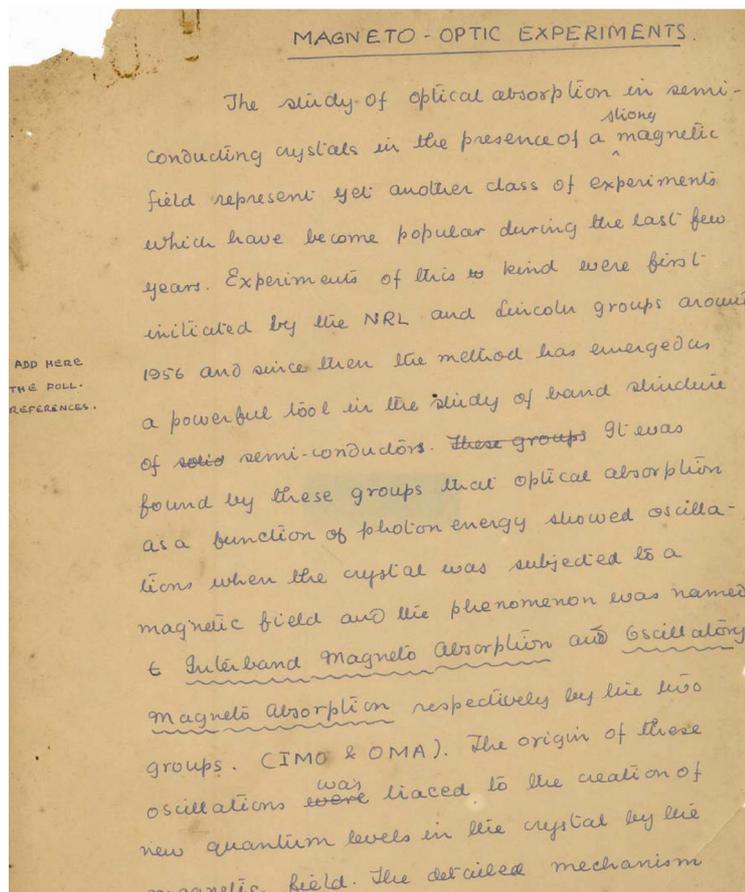


Figure 3. Extract from GV's notes on 'Techniques to study band structure of semiconductors'.



Figure 4. GV and Raja Ramanna at the Indo-German Seminar on Radiation Damage. N. Srinivasan (Director, RRC) is seen addressing the gathering.

far-sightedness. Looking back at that era, one can surely say that for nearly a decade after GV moved to Kalpakkam in December 1973, he and his colleagues, especially those in the Materials Science Division (MSD) pursued with missionary zeal, their desire to create an equivalent of the famed 'Landau's School' that could address all issues of materials damage relevant to fast reactors. While GV surely successfully started MSD as a seat of excellence, with several outstanding results having come out of it over the past four decades, his larger vision of integrating science and engineering at RRC did not fructify in the way he had contemplated. It was partly because the then top managers at RRC held a different view and were not inclined to see the merit and long-term value of GV's approach. At times he had to endure tough situations, and in 1984, when he was awarded the Jawaharlal Nehru Fellowship, it provided him the needed respite from the duties at RRC, so that he could devote more time to his scientific pursuits.

Apart from working on a book (which was later published in 1989 under the title *Beyond the Crystalline State*) and studying different facets of glassy materials during his Jawaharlal Nehru Fellowship period (of two years) and for nearly a year afterwards, GV was also involved in planning the activities of a new institution, the Centre for Advanced Technology (CAT). The genesis of this new centre actually lay in a report prepared by GV and submitted to the Government of India in 1979. In that report, he had proposed the creation of a Na-

tional Centre for High Technology, encompassing a variety of high technology areas that he felt the country needed to embark upon immediately. The proposal eventually led to a positive decision by the Government of India (in 1981) that a new centre must be created, albeit with fewer programmes than GV had originally envisioned. It was also decided that the new centre, CAT, will be within DAE. The first formal order to set up CAT (in Indore) was issued by Raja Ramanna in June 1983, with GV as a member of the Planning and Implementation Committee. DAE also decided that CAT will focus on R&D activities in lasers and accelerators. The foundation stone of CAT was laid on 19 February 1984 by the then President of India, late Giani Zail Singh. By the end of 1984, Iyengar (the then Director, BARC) told GV that he will have to take charge of CAT and also supervise the accelerator activities. Initial focus of the accelerator-related activities at CAT was to set up a VUV synchrotron source along with its injectors. This led GV to interact with laboratories in Europe and USA. While visiting USA in 1985, he set up links with Advanced Photon Source in Argonne National Lab, Advanced Light Source in Berkeley and National Synchrotron Light Source in Brookhaven National Lab. He advised the CAT engineers who were building the accelerators to keep in mind the synchrotron utilization aspects right from the start.

In 1985–86, GV initiated a collaboration with Budker Institute of Nuclear Physics (BINP) in Novosibirsk, Russia,

under the INSA–USSR Academy exchange programme. His idea was to visit BINP, to see their synchrotron set up, so that we can configure our own facilities at CAT in the best way possible. GV was keen that we do some experiments using their VEPP-2M light source; so he got Ajay Sood and myself involved in this activity and arranged that we could stay there for up to three months. He also planned a visit to the Khurchatov Institute in Moscow to see the light source Siberia-1 (which was then under construction) before going to BINP. Due to many reasons our visit got scheduled only for March 1987. By then, although GV was initially appointed Director of CAT, with D. D. Bhawalkar as Deputy Director, due to top-level changes in DAE (with M. R. Srinivasan becoming Secretary, DAE at the end of February 1987), there was a rethink: Bhawalkar was designated as the Director of CAT in place of GV. Since GV had spent years thinking and planning details of the accelerator programme, he was disappointed more than being hurt, that such important decisions with a bearing on an institution can be taken arbitrarily. At the same time, keeping in mind the institutional commitments, he felt our visit (under the Academy exchange programme) must stay on course and begin in March 1987 as planned and that we must go together to Moscow and Novosibirsk. While GV returned (as scheduled) from USSR after two weeks, Sood and I stayed at BINP for two months to finish our work before returning home.

After these unsavory developments, GV decided to leave DAE and accept an offer by V. S. Arunachalam (the then Scientific Advisor to Raksha Mantri and Secretary, DRDO) to start a new institution in Hyderabad and he relocated there as Director, Advanced Numerical Research and Analysis Group (ANURAG) in December 1987. Although nearly three decades have passed, at times I wonder if decision-makers ever made an effort to know the toil and hard work GV had put in, to build a foundation for the accelerator programme at CAT. Surely I cannot help feeling that CAT missed out a great start.

Years later, when Bhawalkar retired as Director of CAT, on 31 October 2003, that responsibility was passed on to me in addition to my duties as Director, Physics Group, BARC. I wrote to GV,



Figure 5. GV addressing participants of a workshop on Microprocessor-based instruments.

and also sought his good wishes. GV's response was prompt, touching and with a deep message. This is what he said:

'My Dear Vinod,

Many thanks and congrats. I am particularly happy because this is what I was supposed to do 16 years ago, and when you take over, you will be really me over there! [in Vedantic spirit!]

Yes of course, all the very best. A few points.

1. Within the ambit that you have, give freedom to the extent possible. But make people realize that freedom comes with responsibility and that freedom comes after responsibility.

2. Tough job, but see if you can foster a shared vision. With god's blessing you can. I shall certainly pray for you.

3. Somehow, the importance of character must be quietly stressed. If character is present, things will work out. Mere brilliance no longer works.

4. I place before you what Weisskopf once said [and I quote this often] "Knowledge [read scientific knowledge] without compassion is inhuman while compassion without knowledge is ineffective".

5. At the present time, progress is most often thru synergy rather than sheer individual brilliance. If you take MRI, it is a superposition of so many things and ideas. If you look at a Sony Digital Camera, it conveys the same message. So, people must learn to work with each other and cooperate, as the Vedas exhorted. In QM, it is coherence that makes lasers and superconductivity possible! Good old superposition principle.'

That message of GV about inculcating a 'shared vision' proved to be invaluable. For in just about two years, starting from an empty area, we put together INDUS-2 and transport line TL-3 and had begun accumulating electrons in the ring, and on 2 December 2005, the first synchrotron light out of the ring was seen. Thereafter, the then Prime Minister Manmohan Singh visited us on 17 December 2005, to dedicate INDUS-2 to the nation and rename CAT after Raja Ramanna. (Our storage rings were named INDUS by GV.) We received a congratu-

latory message from GV, wherein he expressed the hope that over time INDUS-2 will spur new scientific activities in the country. That dream of his has been certainly fulfilled by many younger colleagues, who have over the past decade built several beam lines. A protein crystallography beam line established by Jagannath in 2012 won applause from the macromolecular crystallographic community, especially M. Vijayan (IISc) and as of now tens of protein crystal structures have been solved with the help of that beam line on INDUS-2.

Transition from DAE to DRDO – in Hyderabad

When GV agreed to move from Kalpakam to Hyderabad in December 1987, ANURAG existed only at a concept level, and even some office space had to be provided to it by the Defence Research Development Laboratory (DRDL). (I learnt from GV that initially he and A. P. J. Abdul Kalam had to share an office.) Later ANURAG got some office space at Research Centre Imarat and then a building was made available in the DRDL campus. Initial mandate given by Arunachalam to ANURAG was that it must develop a platform to do intensive computations, like computational fluid dynamics (CFD) calculations, needed in the design of the light combat aircraft. Due to embargoes on the acquisition of supercomputers, GV and colleagues (Neelakantan and Athithan, who had moved with him from IGCAR), quickly zeroed onto building multi-node parallel computing hardware platform, besides developing appropriate software to exploit the full potential of such machines. They decided to move in stages and over time ANURAG had built a 128-node machine that was unveiled in 2004 by the then President late Abdul Kalam.

As for the processor chips, initially GV decided to put together infrastructure for chip design at home, while for actual chip fabrication, he planned to use foundry facilities abroad. This scheme was quite effective; but later, to make this development immune to any future restrictions, GV felt that efforts must be made to set up full facilities for the design and fabrication of processor chips within the country. To enlist support of all the policy-makers towards this viewpoint was a challenge. But thanks to

GV's persuasive skills, the proposal to set up a foundry in the country got support at the highest level of the Government of India. While this was a positive outcome of GV's efforts, the gestation period to make SITAR foundry a reality turned out to be long. Finally, in the 1990s, through a collaborative arrangement between DRDO, Department of Space and DAE, SITAR foundry was set up and made operational by Neelakantan, who assumed charge as Director of ANURAG after GV's 'formal' retirement in October 1992. Over time, SITAR has delivered several chips to users and has also built full systems (based on such chips) for various agencies.

After moving to Hyderabad, GV had to endure problems in personal life. The demise of their son Suresh in 1988 was a tragic blow to GV and his wife (Saraswati), who had to painfully accept it as a harsh reality. Thereafter, while GV immersed himself in his professional life, as well as in writing a series of books (Figure 6), including several volumes under the series *Vignettes in Physics*, that loss took a big toll on his wife's health. For GV writing books was his way to connect with budding scientists (like Suresh) and to inculcate in them an interest towards various areas of physics and great Indian physicists. Having come across many young persons who have enjoyed reading these books and learnt physics from them, it would be no exaggeration to say that GV's books (including what he calls as Junior Feynman lectures) would continue to inspire the younger generation for long, just as original Feynman lectures have done so over the last 50 years. This indeed is a yeoman's service by GV to the young Indian physics community.

Here I must record two events in GV's life (when he was working for DRDO), to highlight how intensely committed he is to any assignment that he accepts. Both the events are connected with 1988, which was an important year for Indian science. It marked the birth centenary year of C. V. Raman (born on 7 November 1888) as well as the Diamond Jubilee year of the discovery of the Raman effect (1928). Thus it was natural that different agencies in the country had planned celebrations in their own ways. INSA and IASc (founded by Raman himself) had decided to publish a scientific biography of Raman, while DAE (with M. R. Srinivasan as the then Secretary) gave

an endowment to the Indian Physics Association (IPA) to start a lecture series called DAE–C.V. Raman lectures. Under this series four speakers were to be selected each year and invited to deliver lectures in four different areas of science and engineering. A directive of DAE was that these lectures be delivered in two local colleges – one in the southern part and other in the northern part of Bombay.

INSA and IASc had assigned the task of writing the scientific biography of Raman to GV, while he was still at IGCAR as a Jawaharlal Nehru Fellow. After he had accepted that assignment, GV began his research on Raman's life and scientific work at a deeply intensive as well as extensive level. But what was even more impressive was that GV decided to interview a large number of persons who had personally known Raman. He also collected a huge variety of historical details by writing to a large number of agencies, both within the country as well as overseas, including the Royal Society of London. The end-product of that monumental effort was GV's book titled *Journey into Light* (Figure 7). It is undoubtedly a masterly exposition of Raman's scientific accomplishments. However, the perceptive and literary style describing the milieu in which science in India was conducted at that time are overwhelming. The book was released by the then Prime Minister late Rajiv Gandhi on 2 November 1988 at a function in Calcutta. Very rightly the venue was the Indian Association for the Cultivation of Science (IACS), the place where Raman had begun his scientific research. While writing the biography was a gigantic task and took more than three years, it was clear that GV was passionately involved in this project. He fulfilled his commitment, notwithstanding the upheavals in his personal life that he had to endure in that period. Surely, the book has won acclaim from one and all, and it will remain an epic for a long time to come.

Due to procedural formalities, lectures under the DAE–C.V. Raman lecture series could commence only in 1989. However, to IPA office bearers, it was obvious that the most appropriate inaugural speaker was GV and the function should be presided over by M. R. Srinivasan, with the Institute of Science in south Bombay as the venue. On that occasion on 27 November 1989, true to Raman's style, besides giving a fascinat-

ing lecture, GV gave a live demonstration of the Raman effect with the help of the light scattering team that he had put together at BARC, before moving to Kalkkham. He used a helium–neon laser and liquid carbon tetrachloride as sample to exhibit the Raman effect and charm his audience. While the lecture was delightful, it was the live demonstration

that thrilled the students, who stayed late to individually 'experience' the Raman effect. I must also quote from the records what Srinivasan had said in his introductory address. After touching upon Raman's life he said, 'It is not my purpose to describe to you the life and work of Prof. C. V. Raman. We could not have found a better person than Dr G. Venkataraman

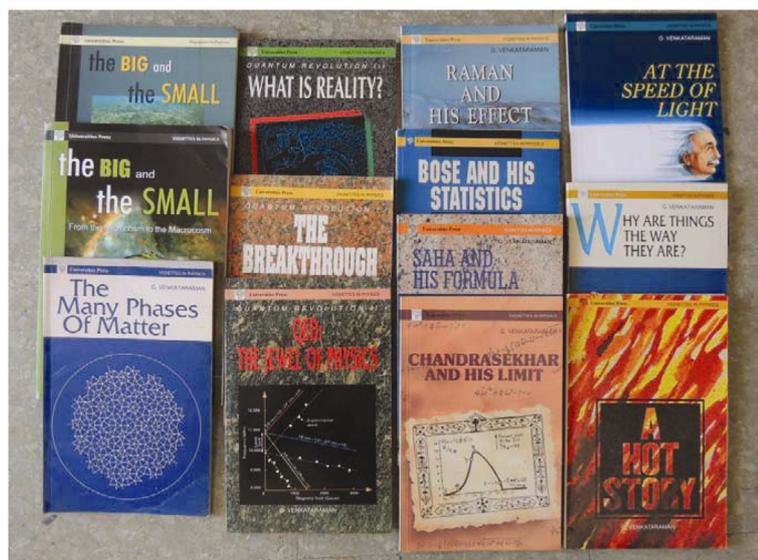


Figure 6. A collage of some of the books written by GV to inculcate interest in physics among young students.

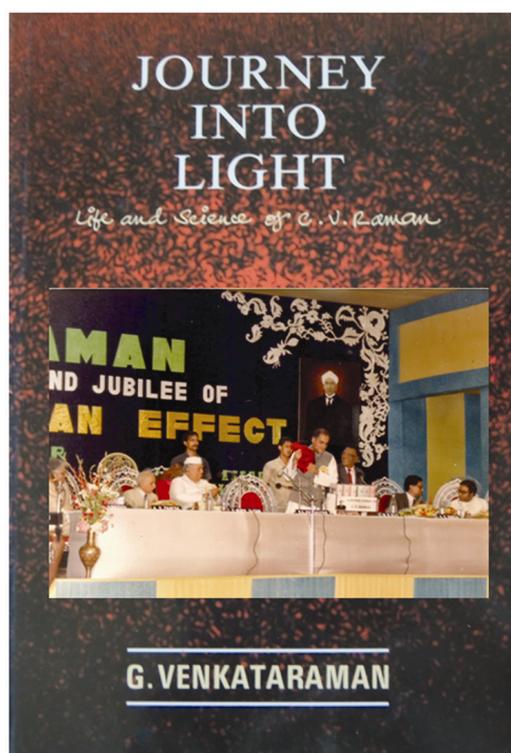


Figure 7. Cover jacket of *Journey into Light*. Superposed on it is a photograph of late Rajiv Gandhi releasing the book.

for that purpose. Some months ago, I read his book "Journey into Light" about the life and science of Raman. I have seldom come across a biography written so well, with the right blend of adoration, sympathy and objectivity. I commend this book not only to understand Raman but also to understand the milieu in which science has to struggle in this country.' As per the directive of DAE, GV delivered the same lecture again at Ruparel College, Mumbai in front of a huge audience. Thus, just as Srinivasan had desired, DAE-C.V. Raman lecture series began gloriously due to GV's fine opening innings and it continues till date.

Untiring efforts in science and spirituality: GV's past two and a half decades at Prasanthi Nilayam

For a few years after his formal retirement as Director, ANURAG, GV continued to help DRDO laboratories in addition to his engagements at Prasanthi Nilayam. He got me involved in DRDL discussions concerning the use of X-rays for tomographic inspection of rockets that use solid propellants. After he had moved to Prasanthi Nilayam, another link that kept me connected to him was the SITAR foundry implementation committee. However, it would be fair to say that such technical engagements were a continuation of what I was always used to in my long years of association with him. For years, after GV's moving to Prasanthi Nilayam and serving as the Vice Chancellor of Sathya Sai Institute of Higher Learning, we seldom moved out of our scientific/technical turf.

However, over the past many years there has been a transformative change in our relationship. It began when he visited Mumbai and exposed me to spirituality. This influence has intensified after my visits to Prasanthi Nilayam. I can appreciate the spiritual development that GV has experienced after being in Prasanthi Nilayam and his two decades of association with Sai Baba. While I cannot say if his connection with Sai Baba was preordained or not, Prasanthi Nilayam opened

a new chapter in GV's glorious innings on the spiritual side of life. A few years ago, he gifted me the three volumes of his magnum opus, *The Miracle of Pure Love: The Story of Sathya Sai Baba*. After reading them, it became obvious that the passion and intensity to strive for perfection is an integral part of GV's personality and that trait of his is an invariant.

Over the past many years GV has generously shared the books authored by him as well as a wealth of lectures he has delivered both under the auspices of Radio Sai (which was largely his brain child) as well at many places all over the world in front of a variety of audience. While I am still at a very nascent stage to appreciate the deeper philosophical aspects of life that these contain, I acknowledge that GV's exceptional communication skills have revealed to me what I had never been exposed to before.

Before I conclude, I must mention GV's deep and passionate involvement over the past few years to set up the new Archives facility in Prasanthi Nilayam. His goal is to create an institution that will house and preserve for posterity all the audio/video tapes, as well as handwritten notes of Sai Baba. It has been a challenge, not only because it involves information retrieval from many obsolete items, but also due to the fact that the modern preservation technologies are not yet readily available in India. So, GV is spearheading a mission to put in place a facility incorporating best practices in modern preservation technologies and he is also focusing on developing proper tools, manpower and manuals so that the facility will last for centuries. The superlative efforts he has put into this venture and his visionary planning leave little doubt in my mind that GV will not only succeed, but that the Archives will indeed preserve that treasure for many future generations to come.

In conclusion I wish to mention that GV has contributed enormously to the enrichment of our nation in a variety of ways. Let us pray that his continued

guidance to enlighten us remains for a long time to come.

Epilogue

I hope my article gives the reader a brief insight into the life of GV and a peek into his towering personality. GV's world view today is that the identity of an individual as a human being comes even before his/her identity as a scientist. He quotes the famous physicist Victor Weisskopf (who served as Director General of CERN) that 'Human existence is based upon two pillars: Compassion and knowledge. Compassion without knowledge is ineffective; knowledge without compassion is inhumane.' Extending this idea one could say that to be considerate to one's fellow human beings (the main message of Baba) is perhaps more important in a professional scientist's life than for others and underpins GV's connect with the spiritual side of life that I have mentioned here.

ACKNOWLEDGEMENTS. I am grateful to many colleagues in the DAE institutions as well as outside, who have generously helped in different ways. M. Sai Baba (IGCAR) graciously went through the archives of his Centre and provided me a number of pictures, some of which have been included here. N. Maheshchandra (Executive Secretary, IASc, Bengaluru) kindly arranged for the photograph made available by the Director, IACS (Kolkata), which was taken on the occasion when late Rajiv Gandhi released GV's book *Journey into Light* in November 1988. I thank my old associates, particularly Ajay K. Sood, L. Madhav Rao, P. R. Vijayaraghavan, P. S. Goyal, B. N. Jagatap, Saibal Basu, G. Ravikumar and S. M. Yusuf for useful inputs, as also S. N. Achary and P. Mathi for constructive comments. I also thank G. Srinivasan for his useful comments on the first draft and for sharing valuable information about the educational institutions that GV had attended.

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