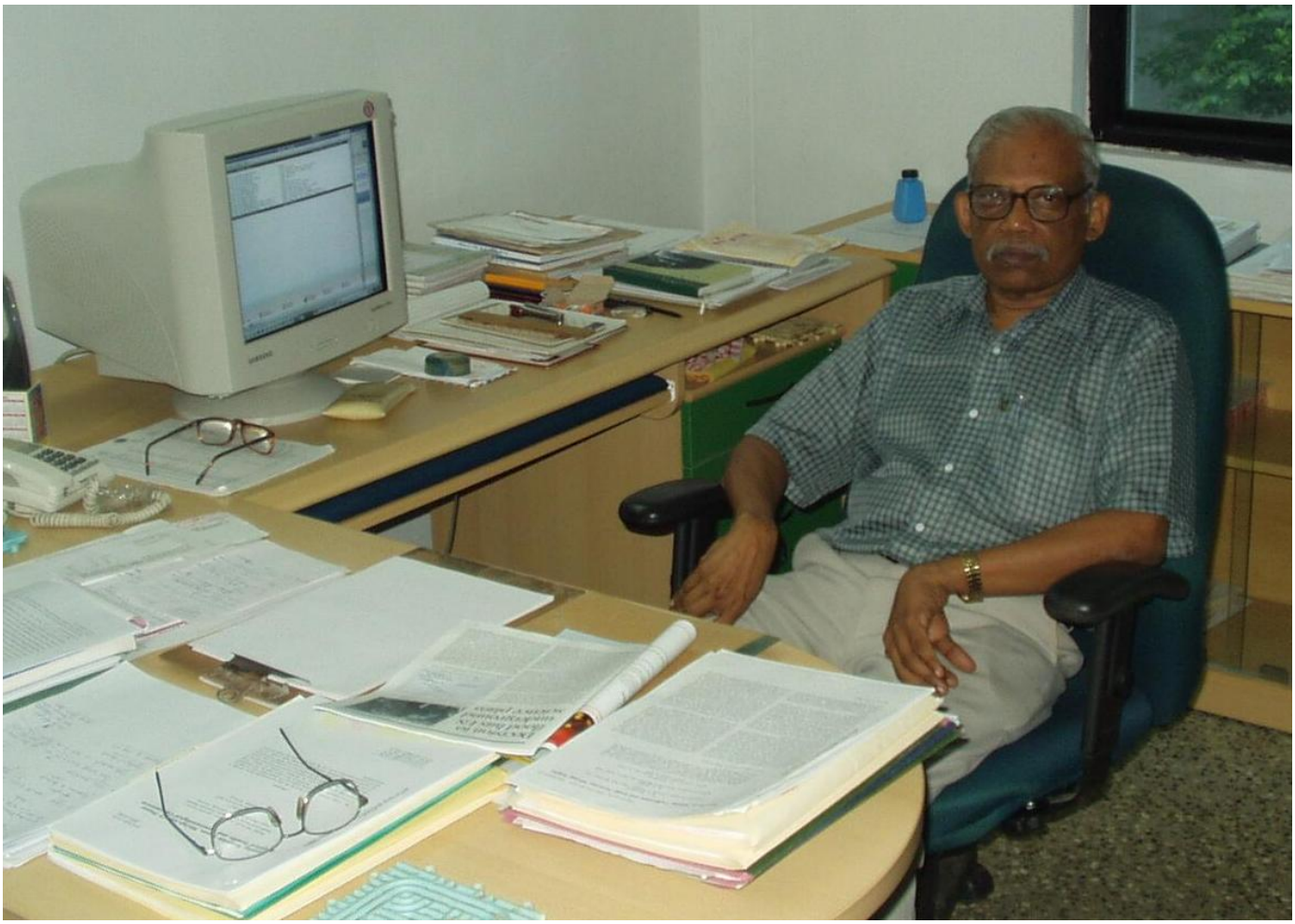
MY INWARD BOUND JOURNEY

G Rajasekaran



Chennai, May 9, 2020

Preface

For more than ten years, Gauri, wife of RP Malik of Banares Hindu University has been persuading me to write my autobiography. Finally I succumbed.

The biography of S Chandrasekhar, the famous astrophysicist, was written by Kameshwar Wali. Chandrasekar himself wrote his scientific autobiography, but did not publish it. Wali published it after Chandra passed away. I got the inspiration for writing my scientific autobiography from this.

So this book has two parts: Part I My Inward Bould Journey and Part II: My Scientific Autobiography. There is some overlap between these two parts.

M V N Murthy has been kind enough to put the whole thing together in the form of a book.

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Chennai

CONTENTS

Part I: My Inward Bound Journey

Early life (1936 to 1952)

> I know not who paints the pictures in memory's canvas; but whoever he may be, what he is painting are pictures: by which I mean that he is not there with his brush simply to make a copy of all that is happening. He takes in and leaves out according to his taste. He makes many a big thing small and small thing big. He has no compunction in putting into the background that which was to the fore or bringing to the front that which was behind. In short he is painting pictures, and not writing history.
>
> (Rabindranath Tagore in his book "Reminiscences")

I was born in 1936 in Kamuthi, a small town in Ramanathapuram District, about 80 Km south east of Madurai. It had a population of about 10,000. There were two main streets, running north-south. One was called Nadar Bazaar and lined with shops by prosperous Nadars. The other was Muslim Bazaar, not so prosperous. (In my recent visit, I found the situation has reversed. The Muslims are very prosperous, while the Nadars have sunk.) In the north of Kamuthi, the river Gundaru ran and on its northern banks stood the majestic fort of Kattabomman one of the early chieftains who fought against the British. That area is rocky and elevated and hence called Kottaimedu. The Nadar houses were mostly on either side of the Nadar Bazaar while the Muslims lived to the west of their bazaar. In the northern part of the Muslim Bazaar were the Chettiars and other communities.

Kamuthi is in Mudukulathur Taluk which is known for ferocious caste fights. Thevars and Nadars regarded Nadars and Thevars respectively as enemies. Once before I was born, Thevars invaded Kamuthi and burnt down Nadar properties. After that every Nadar household had weapons like sickles and spears. That day when the plunder took place is observed every year by special pooja in the Muthumariamman temple. Now the fight is between Thevars and Harijans (Dalits) which erupts even now.

Muthuramalinga Thevar was the leader of Thevars and it was said that he was re-

sponsible for the caste fights. In any case he has been deified after his death. His home at Pasumpon, a village three Km north of Kamuthi just beyond Kottaimedu has become a place of worship. Every year on his birthday, all political leaders make a beeline to visit Pasumpon to pay their respects. All political parties vie with each other in getting the votes of Thevars who form a major vote-bank in Tamil Nadu politics.

There are two Hindu temples Muthumariamman Temple and Meenakshi Temple. There is a Roman Catholic Church and a Mosque. The Muthumariamman temple is in the middle of the Nadar Bazaar and it belongs to the Nadar community. The Meenakshi Temple belonged to the Raja of Ramnad and to the Thevar community. Around the Meenakshi Temple was a small Agraharam where the brahmin priests and teachers lived.

Nadars were not allowed into the Meenakshi Temple. Nadars went to the court on this issue, but the court said that since you have the Muthumariamman temple belonging to you, you cannot enter the Meenakshi Temple! Now all this is over. When I was in Kamuthi recently, I could enter the Temple. My father, VR S S Guruswamy Nadar had a

Figure 1: Circa 1942. From L to R, My grandmother, GR, my father, my uncle Ramalingam carrying my brother Rajaguru, my sister Leelavathi, my mother.

shop selling metal vessels. My mother was Ekkimuthammal. I was the first born and had four brothers and five sisters, one of the sisters died as an infant.

My father's shop did well and so our family was reasonably well- provided, but later my father's earnings in the shop was not enough to provide for such a large family.

My father's father, whom I never saw, was Sivagurunatha Nadar. His father was perhaps Subramania Nadar and his father was Veerabhadra Nadar. So my father's initials start from VR (Veera), then S (Subra), and S (Siva). This is how Nadars were generally named. If I were to follow this practice, my name would be VR S S G Rajasekara Nadar! Although my grand father was not alive when I was born, I was lucky to see my grandmother. She passed away when I was in the elementary school.

My father's family was not well-to-do. My father studied only up to second standard. In fact I heard that the family was so poor that my father made whistles out of palm leaves and sold them to children!

He went to Rangoon and worked as a shop assistant. Those days Indians went to Burma or Malaya just as now they go to USA or Middle East. After earning enough money he returned and got his three sisters married off. Then he married my mother in 1934. As I already said, he did very well through the vessel shop.

My mother's father was MR Perumal Nadar. He went to Penang in Malaya and did very well. He owned his own shop there. He took my mother to Penang for some time. So both my father and mother are foreign-returned!

As ill luck would have it, during the Japanese occupation at the time of the Second World War, my grand father had to convert all his money into Japanese currency which became worthless after the war. He brought all these currency notes and distributed them among children; we used to play with them!

But his return to India was an interesting story. For many years during the war we did not have any contact with him. It was even thought that he was dead. I remember I was persuaded to write a nice letter to him by my uncle Ramalingam (my mother's younger brother) for which of course there was no reply.

Around the year 1947, my father wanted to take our whole family on a pilgrimage to a small town called Yeral. We were waiting for our bus at the bus stand. Imagine our surprise, when Perumal Nadar got down from the bus!

Perumal Nadar was a very interesting personality. He used to take me to the river-side for long walks and advised me to pluck the herbs there and eat them. He was also philosophically oriented and gave me many books to read.

In my younger days my uncle Ramalingam who was looking after our shop took care of me also, like taking me to the well (called Nandavanam) for bath, when my father was not there. In fact most of the time I was with him in the shop.

There were two deaths which affected me very much in my childhood. My baby sister Kanthimathi and my aunt (Ramalingam's young wife). The latter died while giving birth to her first son. She was very fond of me.

I had three aunts (my father's sisters) Mookkammal, Thenammal and Sornammal who lived in another small village, Kokkarankottai. Thenammal lived in Aruppukkottai, another town. Mookkammal lived in Kamuthi. Her husband died before I was born. She liked me very much and I visited her small hut often. She was very poor, but always gave me something to eat. Once she could give me only rice mixed with brinjal cooked in oil. It was so tasty that even now I like brinjal cooked that way. My father's elder brother Rangaswamy Nadar had a vessel shop in a neighboring town Abiramam, but did not do well.

There was a Sankara Mutt in Kamuthi. A few Nadars and maybe some from other communities belonged to the Mutt. My aunt Mookkammal also belonged to it. They were all vegetarians. Once a year there was a pooja and meals were served. My aunt took me there.

Another person I liked was my maternal grand mother's sister Meenammal. Tragically she had lost her husband and son some time ago. She liked me very much and as a child I remember to have spent much time with her in her humble hut. She was very poor and eked out a living by selling the milk from one or two buffaloes that she kept. She used to carry me on her rounds selling the milk.

My father along with another Nadar ran a Cinema Theater. I still remember my father taking me on the back seat of a bicycle to watch the films. But I heard that my father lost a lot of money since the other person cheated him. I also heard that the only film that ran well and so earned some money for him was "Rajasekaran" and that is why my father named me that!

The very first film that I understood was Nandakumar. My uncle Ramalingam took me for it. TR Mahalingam acted as young Krishna and I liked it. Another film that I liked and still remember is Laila Majnu. There were two versions: one with Nageswara Rao and Bhanumathi with Gantasala's songs and the other with TR Mahalingam. Much later when I was in American College, Madurai, I saw Devadas (with Nageswara Rao and Savitri) and I liked it very much.

The other films that I liked were Bhaktha Meera (MS Subbulakshmi), Shakunthalai (MSS), Savitri (MSS), Sivakavi (MK Thiagaraja Bhagavathar), Thiruneelakandar (MKT), Haridas (MKT), Chakradhari (V Nagiah). The other singing stars that I liked were PU Cinnappa, TR Mahalingam and KB Sundarambal.

There was not much industry in Kamuthi. But I can mention a few things of interest. RM T S Soundara Pandian's family was well-to-do among the Nadar families and they had earned their money by leather business from the time of RM T S S's father Senthilkumar Nadar. They bought the skins of the slaughtered goats, treated them and after further treatment in their factories in Dindigul and Trichy, sold them. Some were even exported abroad.

RM T S S was an important Congress leader in the district and knew Kamaraj who visited Kamuthi a few times. He was elected as the President of the Panchayat Board. My wife is his daughter. He named her Suthandra Devi (Goddess of Liberty) since she was born just after India got independance. He passed away during the election propaganda when he was talking in support of the Congress candidate.

Another prosperous family in Kamuthi was the family of PNSP Palanichamy Nadar who made their money by making snuff from tobacco. Their firm was known as Chokkan Palani Vilas. Their shop was adjacent to ours and Periaswamy, the eldest son of Palanichamy Nadar, liked me and my family had good relations with him. He was many years older than me.

My father brought brass sheets from factories and through the metal workers called "kannars" in Tamil and who lived in Kannarpatti in the northwestern part of Kamuthi made vessels which were then sold. This was essentially a cottage industry and could have grown up to factory level, but didn't.

Opposite our vessel shop was what was called "kittangikkadai". Kittangi is godown and it was used to store rice in gunny bags. It belonged to SS Ponnuswamy Nadar whose shop and house also were right there. His son Ramasamy was a friend to me and Ramasamy's cousin Rajarathinam (alias Jeyaraja)) also was my friend.

A little distance from the southern edge of Kamuthi, recently Adani and Co set up what was claimed to be the world's largest solar power plant. They got the lands cheaply since they were fallow lands. However this has not yet contributed to the industrial development of the region.

One thing that stands out in my memory of those childhood days was our visit to Madurai and the Meenakshi temple. On the way to Thirumangalam to worship our family deity there, we used to stop at Madurai. In addition my father used to take me some times to Madurai. He went to Madurai periodically to buy the vessels to be sold at his shop in Kamuthi. I always enjoyed these trips. The majestic sky-high gopurams and the gigantic temple where every corner had a historical or mythological story to tell. The temple was surrounded by roads forming a series of concentric roads forming squares, each named

after a Tamil month. The Old Madurai City was so well planned. My father knew so much about the City and the Temple which he conveyed to me. I decided that when I grow up I will live in Madurai!

In the beginning we lived in Ramalingam's house. Sometime in the 45-47 period we moved into a very big house which my father took on lease. It had two storeys, many rooms and terraces. Third storey was a open terrace and from there we could see the fort at Kottaimedu, since our house was the tallest building in the whole area.

The house had a backyard where we had a cow. We children were afraid of going to the backside of the house since it was dark and we did not have electricity. Cobras were suspected to be around. A snake charmer was called and he caught one cobra from inside one of the rooms at the back and one in front of the house where there was an empty space. Some people said the snake charmer brought his own cobras and pretended to catch them!

One night my father was bitten by a small snake in our terrace upstairs, but probably it was a non-poisonous snake.

But there were many scorpions and I was bitten by them a few times. Although it was intense pain, it lasted only twenty four hours!

Those days the shops remained open even on Sundays. Then the Government passed an order that all shops must be closed on Sundays. So every Sunday my uncle Ramalingam and a few of his friends (which included Periaswamy) used to make poories in the terrace upstairs and it was a very enjoyable occasion. Poories were a novelty at that time. In fact wheat itself was unknown. During the war rice became scarce and government introduced wheat into Tamil Nadu.

Another joyous occasion was full-moon days when my mother along with a few neighbours used to cook special meals (called koottanchoru) in the terrace. All this happened when we were living in my uncle's house.

Once I traveled with my brother Rajaguru by bullock cart to a neighboring village called Kollangulam. There Nadar community had landed property along with a farm-house. My grandfather was working there as the man-in-charge. He had invited us there. We spent a whole day and night. Recently, after more than 70 years I visited Kollangulam with Rajaguru.

The Nadar community earned quite a bit of money from the land and the Muthumariamman Temple was managed with those funds. The community had a local government called "uravin murai" which even levied tax called "mahamai" from every Nadar family.

The first educated Nadar from Kamuthi was Dr M Natarajan who was the son of

Mahalingamurthy Nadar who was a formidable character. People have seen him beating his son with the stick part of a palm-leaf fan. Once a widow was punished by the uravin murai for crossing into the forbidden muslim street. He fought against that and the uravin murai decreed he should apologize by symbolically breaking a coconut in front of the deity in the temple. He refused to apologize and the uravin murai expelled him from the community. He left Kamuthi and thereafter lived in Madurai.

After getting MBBS, Natarajan served in the war effort. He went to Japan and treated the wounded British and Indian military men. So he was awarded a high military rank. After the war, he settled in Madras and became a famous orthopedic surgeon. He rose to become the Principal of the Madras Medical College.

Natarajan is a relative of my wife and a distant relative of mine. My father used to say that if one wants to get educated he should take Natarajan as his model.

Kamuthi was an important market-town for the surrounding villages. Every Tuesday Kamuthi became a Sandhai (market). People from the surrounding areas came on that day and bought or sold things. This activity took place mainly in a special area called Sandhai, located in the southern part of Kamuthi. The whole town was full of people on that day. There was very brisk business in all the shops including our vessel shop.

School (1941 to 1952)

I studied in Kshatriya Nadar Higher Elementary School up to the fourth standard and in Board High School from fourth to the eleventh standard which is the end point of school education those days.

Among my teachers in the elementary school, I still remember Ulaganatha Iyer, Subramania Iyer, Subramania Pillai and Alagu Ramaswamy Pillai who was an excellent teacher.

During the school days, I spent all my time after school, at our shop. In fact in my father's absence I have sold many vessels. But my heart was not in this business. Since the vessel shop was not busy most of the time, I could concentrate on my studies. I came out first usually in most subjects.

Apart from the shop, there were two other places which I frequented. One was Muthumariamman Temple and the other was Nadar Vidhyabiviruthy Sangam which was a library. There were newspapers and monthly magazines. There were old books too. Among them I found a book of science where Thomson's atomic model was described. It also contained Michael Faraday's discovery of electromagnetic induction with excerpts from his diary. I enjoyed reading them and it created in me an interest in experimental

science.

The Sangam was under the care of V Saravana Nadar who was a distant relative of mine. He was a bachelor and lived in the Sangam premises.He cleaned up the premises and took care of the reading room and the library. There was a radio upstairs that was also under his control. News by All India Radio and good carnatic music emanated from the horn loudspeaker. We got the news about Gandhiji's assassination on 30 January 1948 from this radio. Our house was a little distant from the Sangam, but the direction of the loudspeaker was such that I could hear the music sitting on our upstairs window, especially in the nights. This was my first encounter with beautiful carnatic music!

Now a guest house with AC rooms and attached bathrooms has been added to Sangam and I stay there during my visits to Kamuthi.

I was very much attracted by the Muthumariamman Temple which was close to my home. I liked to watch the priest doing pooja to the deity and went with the deity in all the temple processions during the festivals.

In 1945 Germany was defeated in the II World War and it was celebrated in India which was under the British rule at that time. So the Union Jack was flying over the Tahsildar's office. After a while it was removed. I asked my father why was it removed. Like most children I liked the colourful flag. My father said in any case it was not our flag, we were being ruled by the British. That is the first time I became aware that we were not independent.

When I studied there, the Kshatriya Nadar Higher Elementary School had only up to eighth standard. It started maybe a century earlier. Later, after my time there, this school became a High School with classes up to twelve. Although it has the Nadar name, it caters to all the castes. In fact now most of the students are from the surrounding villages and students from other castes, especially Thevars. Hence the School administered by the Nadars has been doing good social service.

A few years ago, the Nadar School celebrated the Golden Jubilee of its High School version and I attended it.

At school a Muslim boy was saying Gandhi was sent to the jail. I asked who was Gandhi. He said he was Jinnah's opponent. That was the first time I heard of Gandhi.

Maybe it was 1946. There was news that Gandhiji was coming to Madurai. My father planned to go to Madurai to see Gandhiji. I requested him to take me with him and he agreed. But unfortunately, my father could not go for some reason and I lost my only opportunity to see Gandhiji.

Actually, it was neither Gandhiji nor Nehru but Netaji Subhash Chandra Bose who was

popular among the youngsters. All of us carried a photo of Bose in military uniform in our pockets in defiance of the British Government who considered that as a punishable offense.

Independence came in 1947 and on that day I was not in Kamuthi. My father took all of us to Yeral, a pilgrimage town, the same trip which was postponed due to the arrival of my grandfather. We were all sleeping in the Chathiram of the temple on the night of 14 August 1947. We were woken up at midnight because they wanted to clean up the Chathiram on the eve of the Independence Day. Next morning Lord Subramanya during the procession was wearing a garland made of charka-spun threads. That is how we celebrated Independence of India.

Since I was a top student in the elementary school, my father's friends advised him to shift me to the High School after I finished class four. When my father took me from the elementary school to put me in the high school, it was Chellappandian, the class five teacher in the high school who took charge of me. He asked me to write an essay on "The Cow" in English. Since Alagu Ramaswamy Pillai at the Elementary School had taught me English, I could write " The cow has four legs and one tail....". Chellappandian admitted me into class five.

Apart from Chellappandian, I had many excellent teachers in the high school - Edward Muthuswamy Pillai, Chellam Pillai, Karuppaswamy Thevar... and above all Subramania Iyer, the Head Master and English teacher for class eleven (which was called sixth form). The way he taught Shakespeare is still ringing in my ears! He trained me to act as Mark Antony in the Annual Day of the School and my rendering of Antony's peroration after Julius Ceaser's assassination was a great success! The local doctor Thirunavukkarasu recalled it whenever he saw me and congratulated me.

There was a custom of putting up the day's news in a black board at the morning's prayer meeting at the school. Following the Headmaster's command, I chose the headlines from The HINDU every day and put it up. This also gave me good practice in the English language.

There is one incident I cannot forget. In class eight (third form) there were two sections taught by Edward and Chellam Pillai. Since Edward had impressed me very much as a good and interesting teacher in the second form, I wanted to go to the section of Edward. But I was put in the other section. They did not allow me to change the section since that was apparently against the rules. I was very disappointed.

But what happened afterwards proved to be an anticlimax! Chellam Pillai turned out to be an excellent teacher. Not only that. Since I was the first in the class and especially

because he liked me, he made me the monitor and put the whole class under me. In the class tests, I was asked to invigilate with powers to punish the wrong-doers!

We were taught Tamil by two Tamil Pandits, Koormavatara Konar and then Heramba Iyer. Both could compose Tamil poems on the spot. In fact the latter when he scolded the students, it was in the form of a poem!

Hindi was taught in the high school, but then the Hindi agitation by DMK caused the abolition of Hindi teaching. The Hindi Pandit Nagarajan lost his job. A few of us who wanted to learn Hindi paid Nagarajan and he taught us. He was a very good teacher and I passed the Prathamic, Madhyama and Praveshika examinations conducted by the Dakshina Bharatha Hindi Prachar Sabha. I do not remember whether I went for the Rashtra Bhasha examination also.

Karuppaswamy Thevar was our manual training (carpentry) teacher. But apart from that he taught us Thirukkural since he was a great admirer of Thiruvalluvar. He was also a staunch advocate of vegetarianism, but more on that later.

A big problem with the high school was the absence of good teachers for science. Since Kamuthi was a backward area, even the teachers who joined left soon. We did not have a teacher for Maths. As a result my school abandoned Algebra and Geometry and only Arithmetic was taught. Algebra and Geometry were called Composite Mathematics and it was not done. So when I go to College I would not be eligible for First Group (Mathematics, Physics and Chemistry). But my good Headmaster advised my father to buy the standard text books on Algebra and Geometry and advised me to learn them by myself. This is how I spent my vacations.

So my knowledge of Mathematics had many gaps. In spite of that I got first group in the College.

The High School was situated at the southern end of the town. It was just thatched sheds. When I had completed the High School, it shifted to pukka buildings to the north of the town, at Kottaimedu. The Chief Minister inaugurated it. It continued for many years, but now I hear it has been converted into a College!

When I was in Kamuthi recently, I had a surprise. I went with my brother Krishnamoorthy to the location where my old school in thatched shed was situated. It was still there! Actually after the Board High School shifted to Kottaimedu, the shed housed a Muslim School. That also shifted and they were going to demolish the shed, but they had not done it when I visited. So I was very lucky to see my old school!

We had a cow at home. The cow and its calf were sent outside the town for grazing every day. One day the cow alone returned. It was noticed fairly late in the night. My

father and myself went with a torch and we could locate the poor calf which was huddling against a wall. Every one was happy to see the calf.

Another time, I lost my gold ring while playing football in the high school. Again it was noticed only late in the night. My father and myself went to the football ground in the high school. Even though the football field was very big, I managed to find the ring!

There was no electrical connection at our home, but the shop had it. So not only myself, but all my brothers and sisters also studied in the evenings at my shop. But my studies continued even after the shop was closed, especially during the exam period. So I used to study in the light of a kerosene lamp sitting in the bed. Once I fell asleep and the open kerosene lamp fell. A serious accident was averted only because my parents noticed it in time. After that I was forbidden to study in the bed.

I passed out the government examination, called SSLC (Secondary School Leaving Certificate) exam, with good marks and went to study Intermediate in The American College in 1952. This was a big step in our family. By that time our shop was not doing well and my father needed me to help him. My uncle who was helping him in the shop left him and started his own vessels shop which was a rival to our shop. My mother did not like my going away. But my father wanted me to pursue higher education. His idea of higher education was either to go for the IAS examination or start a big business with the help of my education.

Where can the money for my higher education come from? Clearly my father could not afford it. I got a loan scholarship from Nadar Mahajana Sangam which had to be repaid. I also got a merit-cum-means aid from the Madras Government. None of this was enough since the hostel expenses were high. My father had to take it from our shop which went down further as a consequence. Later I could compensate him but that was much later. Even from my Training School stipend of Rs 150, I could send him a large part of it. I continued to do it from my TIFR salary. Since TIFR continued to pay my research assistant salary when they sent me to Chicago I sent him the whole of it. Not only that. I saved a large part of my assistantship money in Chicago and sent it. As a consequence he could build a new house. Until then we did not own a house.

One reason our shop did not do well was this: my father bought some land and he could not concentrate on the shop. From land also he did not get any income since we were in a rain-deficient region.

Among my brothers only one, G Krishnamoorthy could rise high in education. He became a Professor in TIFR. He was financially supported by me after I began to earn. Another, Arunachalam also was supported by me and he got employed in a bank. The

oldest of my brothers, Rajaguru became a successful businessman. He along with his three sons became manufacturers and traders of furniture at Madras. Ramachandran did not study well and never did anything. He died some time ago. Among my sisters none completed school education although two of them did very well in elementary school. Unfortunately, my mother stood against their education and even my father could not do anything.

Actually after my father's time I wanted that our house and other landed property must go to my sisters only since none of them was well-to-do. My mother and brothers did not agree and did not want any part of it to go to my sisters. I did not want to take any part of it although the house was built solely from my money. I cut off all connection with all of them and Kamuthi. After many years, all this has been forgotten and now I have good relationship with all of them. I went back to Kamuthi only after 40 years!

The American College, Madurai (1952 to 54)

Intermediate was roughly equivalent to the present plus two. In spite of some gaps in my Mathematics, I was admitted to the first group consisting of Maths, Physics and Chemistry.

American College was an exhilarating experience for me. The stately buildings and the excellent faculty of the college impressed me very much. I stayed in the Wallace Hall which was one of the three hostels. ES Moses taught me physics and Ramaswamy taught me chemistry. I have preserved the excellent notes of Ramaswamy's lectures that I took. T Natarajan, Benjamin Gunaraj, Gift Siromoney and a few other very good teachers taught mathematics.

I had two very good friends in the college. K S Ramakrishnan who went for IAS and later resigned because of his honesty. I have very good contact with him. The other, M Pathamuthu became a Gandhian and lives in a village near Madurai.

It may be 1953 or 54, Nehru visited Madurai. I had come home on vacation. I wanted to see Nehru. My father permitted me to go. The whole temple city was decorated to welcome Nehru. He was supposed to pass through the road in front of American College. My friend Pathamuthu and myself stationed ourselves at a vantage point inside the college campus. When Nehru's car came near the college, a group of DMK fellows threw something at Nehru's face. It was stones inside a black cloth. For a moment Nehru's face showed his pain but his smiling face appeared soon. I hated this barbaric act by some of the MCC students.

During one weekend, myself and a few friends (Pathamuthu, Sakthivel and Solaivasaham) went on a trip to the Alagar Koil which was in a neighboring hill to the north of Madurai. It was a nice picnic.

Alagar Koil is a famous temple for Lord Vishnu (Alagar). During the Chithirai festival of the Meenakshi Temple, Alagar comes down to Madurai and in the early morning enters into the river Vaigai. Lakhs of people come to witness this event.

During a recent visit to Madurai, I was lucky to witness this event of Alagar entering Vaigai.

It is said that Alagar, that is Vishnu, being the elder brother of Meenakshi, was coming down to give her away in marriage to Lord Shiva. But Vaigai was in floods and he was delayed. The marriage was held without him and Alagar returned to his abode in anger.

There was religious instruction for Christians and moral instruction for others. My moral instruction class was taken by an Economics Professor KJ Charles. His lectures were fantastic. He lectured on Marcus Aurelius, Thomas Aquinas and Albert Einstein. I learnt about Einstein in a moral instruction class!

But I had heard Einsteins's name from my Tamil Text book in the high school. Mu Varadarasanar's article mentioned the famous lines of Kaniyan Poongunranar in a Purananuru poem "Yathum ooray,yavarum kelir" (All places are mine and all are my relatives). and called the poet the Einstein of social sciences!

A crucial event occurred during the American College period. A friend took me to watch the night sky from the terrace of the Mathematics building. It is a look through the College telescope that determined my trajectory in this life.

It just happened that it was the best time to observe the Moon. When it is dark of course you cannot view it and when it is fully bright it does not show its features clearly. But that day was the half-way point between New Moon and Full Moon days. The shadows cast by the mountains in the Moon got elongated, with sharp edges. I felt as if I was standing on an elevated height above the Moon, looking down. It was so frightening, the mountains and craters. It was a fantastic experience. I realized

"There were more things in Heaven and Earth than were dreamt of in my philosophy".

Since Science alone held the key to these other "things" I had no hesitation in my choice of what I wanted to do. I am sure many others too have been lured into Science through Astronomy.

I went to the Daniel Poor Library (It was not a poor library at all! Poor was the name of the donor of the library in the College. It was a well-provided library.) and borrowed many interesting books. Eddington's (or is it James Jeans) "Expanding Universe", George

Gamow's "Life and death of the Sun" are some of the books that I read and enjoyed. My interest in Astronomy and Physics increased further. I published my first article "The Mysterious Universe" in the College magazine.

At the end of my intermediate in 1954, it was clear to me what I should do. I must pursue Physics. In those days Madras University had a programme for keen students called Honours. But it was offered in very few colleges and it was tough to get in. My father of course agreed, in spite of my mother's objections.

Madras Christian College (1954 to 1957)

B Sc (Hons) in Physics was offered in St Joseph's College, Trichy, Madras Christian College and Presidency College. I applied to St, Joseph's and Christian. I got admission in St Joseph's. I had secured very good marks in the intermediate exam, so I should have got admission in Christian College also which is the preferred choice. There were postal delays in getting my marks from Madras to Kamuthi and then from Kamuthi to the College. The eleven seats in Christian were already filled. So I was offered Maths Hons. But I was told that I can shift to Physics if a vacancy arises due to someone leaving for engineering.

I decided to take the chance at Madras Christian College (MCC). I attended the Maths Hons class but the lectures were too dull for me. Everyday I went to the Principal's office and enquired about the Physics seat. The Principal's secretary Ernest will tell me as soon as he saw my head at the window "No". I was getting frustrated. Meanwhile there was pressure from my mother to return and look after the shop.

After many weeks, the miracle happened. The secretary told me that Mr Kannan has left BSc (Hons) to join Engineering College. I felt Lord Krishna (Kannan, in Tamil) Himself came and rescued me!

I got what I wanted and concentrated on Physics. The lectures by PK John, SS Thangaraj, CB Rajagopal, KB Rajangam and above all, Dr MA Thangaraj were excellent. KB Rajangam taught Bohr's model of the Atom and it was so good. I cannot forget them. After that, Thangaraj the Head of the Department taught Quantum Mechanics. He used Rojansky's book. Those days (1956-57) that was the only book on Quantum Mechanics.

The books that I liked were Modern Physics by Richtmayer and Kennard, Heat and Thermodynamics by Saha and Srivastava and Properties of Matter by Newman and Searle. The last book had many problems and I enjoyed solving them during vacation. They were

not mere numerical problems. The problem had to be formulated in terms of equations which had to be solved.

Thangaraj also taught Wireless and Electronics. That was the only subject that I did not like, although that was supposed be the special subject in our Hons course. Every other subject was taught as Physics, but this was taught more like an engineering subject, just a set of prescriptions. Instead of using the standard prescribed text book by Terman, he was teaching from the Admiralty Handbook of the British Navy! In the Wireless and Electronics exam, I almost failed. Thangaraj was also my hostel warden. He called for me in the hostel next morning and scolded me thoroughly. For a big question I had answered but had crossed it out. He said it was a correct answer and I should not have cancelled it. But he passed me nevertheless!

During 1956-57 the syllabus changed and MA Thangaraj found that none of the faculty could teach according to the new syllabus which was considerably advanced. He assigned the tutor TN Seshan to teach all the subjects to us in the final year of the course. Seshan did a marvelous job. Later he passed the IAS exam with first rank and became a very famous (but not popular) administrator. The high point of his career was as Chief Election Commissioner when he reformed the whole election process in India.

On weak ends I traveled from Tambaram to Thiruvallikkeni and went to the University Library. Among the things that I read there were the original papers of Rutherford discovering the atomic nucleus through scattering by alpha particles and Niels Bohr proposing his model of the atom. It was a special fascination to read these classic papers.

The specialty of the MCC (Madras Christian College) situated in Tambaram, a suburb of Madras was the Hostel system. There were three hostels St Thomas Hall, Bishop Heber Hall and Selaiyur Hall. I belonged to St Thomas. Not only the out-of-station students but the so-called day-scholars also belonged to one of these halls and developed an affinity towards the hall to which the student belonged. Only the lectures and laboratories were in the College. All the extra-curricular activities were in the halls. I had two classmates who were my friends Ratnaprabhu and Mahalingam. Ratnaprabhu became a textile engineer and rose to the level of the Director of Ahmadabad Textile Institute and Mahalingam became an officer of Indian Airports Authority.

On a Hostel Day, MK Thiagaraja Bhagavathar was invited. He talked and sang. I regret that I did not talk to him. For, later I became a fervent admirer of his devotional songs. His golden voice captivates me. There is none like him.

While at MCC we had to attend intercollegiate lectures at Presidency College and Alagappa College of Technology. Two series of lectures were memorable. One was by

G N Ramachandran who lectured on General Theory of Relativity although I was still not academically mature enough to understand GRT fully. The other was by Alladi Ramakrishnan who lectured on the Matrix version of Quantum Mechanics which had not been taught at MCC. He was such a powerful lecturer that I was impressed very much.

Here also there were moral instruction classes; they were taken by Kibble, a Professor of Mathematics. He used to let us do anything quietly when he was looking at his book! There is a good story about his absent- mindedness. One day he wanted to go to the city and boarded the electric train. He took his book and began to read. After a few hours he noticed that he was still in Tambaram station. He accosted a railway official and asked him why the train did not leave after so many hours. The official said " Professor, the train has made two trips to Beach station!". That was Professor Kibble.

His son is the famous theoretical physicist TWB Kibble who was born in Tambaram and spent his childhood in the MCC campus. He is the author of the nonabelian version of the famous Higgs mechanism. Later during the Golden Jubilee celebration of IMSc, I invited him to the Institute and took him to MCC where he enjoyed seeing the places of his childhood days. He could even identify the tree which he used to climb!

I was staying at St Thomas with Villimadan, also from Kamuthi, one year senior to me. One day Karuppaswamy Thevar, our teacher from Kamuthi visited us. We hid the fact that we ate at the non-vegetarian mess and took him to the veg mess. The fact that I had to hide the truth from my teacher affected me very much.

Apart from the above, there were other things. At home everybody was a non-veg. Since I was the eldest son, I was sent to buy meat. I had to go every Wednesday to the slaughter-house. One day I witnessed a goat being slaughtered. I saw my mother putting live fish (ayirai meen) into boiling water. Every Deepavali day in the early morning my mother would cut the neck of our pet hen which was screeching. All these events, along with the teachings of Buddha, Gandhi and Thiruvalluvar made me to take the following step.

I shifted to the veg mess. But when I went home on vacation, my father learnt about it and chided me and compelled me to shift back to non-veg mess. I had to do it. He said vegetarianism will ruin my health. I argued by citing the example of brahmins and others who were vegetarians. He would not agree.

So I had to take non-veg food and could become a vegetarian only after I went to Bombay and so became free of my father's influence.

A tragic event took place in 1956. My friend Villimadan died in the big train crash. The Thoothukkudi Express fell down from the bridge at Ariyaloor with considerable number of

deaths. Villimadan perished in that. He was on his way to a job interview. After hearing of this accident, the Minister for Railways Lal Bahadur Sastri immediately resigned. Such honesty and selflessness has been very rare in Indian political circles.

In the year 1956, it was announced that CV Raman was going to lecture at the Presidency College. Thangaraj asked us to go and attend the lecture. I think he also attended.

Raman lectured on his theory of specific heat based on the discrete frequencies of the crystal vibrations and contrasted it with the continuum theory of Peter Debye. At one point his voice rose and he said "Debye's theory is not worth the paper on which it is written". So saying, he threw the sheaves of paper in his hand and they flew over our head and fell into the waste basket. We were all very much impressed. Bored as we were with many uninspiring lectures in the class rooms, we felt this is how lectures must be given!

The examinations were very tough. I had to revise the whole subject and keep it in my fingertips, otherwise there was hardly any time to complete the paper. So, many times I used to stay awake whole night before the exam. Such a thing happened before the Electricity and Magnetism paper which was the last one. After the exams I went to Kamuthi and there one morning I noticed that my eye-balls did not move. For seeing anything which was a little to the right or left, I had to move my head! My parents became alarmed and it was decided that next day I must be taken to the famous Dr Joseph's eye-hospital at Trichy. Those days that was the only place for eye ailments. But miraculously, the next day my eyes became completely normal!

While I was in MCC, scientists from TIFR (Tata Institute of Fundamental Research, Bombay) conducted many cosmic ray experiments in the College grounds. They sent up balloons to the upper atmosphere and recovered the instrument package after many hours. The instrument was special photographic emulsion that recorded the cosmic ray particle tracks. So I had the opportunity to meet many TIFR scientists who visited the College and gave lectures. Bernard Peters, MGK Menon, RR Daniel, D Lal, Gokhale, G Venkataraman. PJ Lavakare. I decided to pursue research in TIFR.

Thangaraj had a research project on Cosmic Rays. He sent nuclear emulsion up by baloon and recovered them after a while. The emulsion contained the tracks of particles that he studied with some research assistants. To recover the baloon one has to track it during its flight and note the direction of its fall. Once a baloon was almost lost and he asked his students to search for it. We were lying on our back on the terrace of the meteorological observatory of the Meenambakkam airport and peering through binoculars.

I succeeded in sighting the baloon and so later it could be recovered! Everybody including Thangaraj was happy.

The Training School (1957 to 1958)

Homi Bhabha had this great idea of the Training School where he could develop the human resources needed for the Atomic Energy Programme instead of taking away scientists from the existing scientific establishments and universities.

It is now called BARC Training School, but the name at that time was AEETTS (Atomic Energy Establishment, Trombay, Training School) and it was to start in August 1957. So it was just right for me since I had completed my Hons degree at that time.

I applied and was called for interview in Bombay. I did the interview well, but admission letter did not come. Got frustrated and went to American College for interview for the physics lecturer's job. SJ Savarirayan was the Principal and Head of the Physics Department. After the interview, he asked me to join immediately. I told him that I am expecting a call from Department of Atomic Energy Training School. If I do not get it, I will come. He was greatly surprised: I am offering you a lecturer's post straight after your degree and you want to go to some school! He had not heard of Department of Atomic Energy those days! Finally I got the letter from Bombay and joined the Training School.

Bhabha chose Dr Raja Ramanna to be in-charge of the Training School, and chose Dr K K Damodaran to be its active head. Dr Damodaran organised all the daily activities of the School and took good care of all of us. We (the trainees) used to refer to him as the "Headmaster" of the School (among ourselves), but he was much more than that, he was almost the local guardian for all of us.

Bhabha had a predilection for appointing military men as administrators. Perhaps he felt that only military men could control the unruly crowd that we were! He appointed a military person Suraj Prakash as our warden. I remember him as a tall and handsome young man, but there was some problem and he was rather unceremoniously replaced by Colonel Ottley. More about the Colonel later.

Bhabha gave an inspiring lecture on the opening day of the Training School. He talked about his dream of bringing nuclear energy to this country and told us how he expected the trainees to help to realize that dream. But at the end of his talk which was aimed at the sky, we were brought down to earth by a question from the audience (namely one of my would-be trainee colleagues). He asked what job we were going to get, after the training period. Nowadays it is common to find that young people are mostly career-minded. They

want to know what they will get after one year and what after 5 years etc. Asking for the so called career-profile has become the standard procedure. Fifty years ago that was not the done thing. Most of us had our mind on the sky and were not practical-minded. That was why we were taken aback by the above question from our colleague. But Bhabha answered the question very effectively. He said the questioner can take his (Bhabha's) job if he proves himself! Bhabha was not bluffing, for a trainee from the 6th batch of the School (Dr Anil Kakodkar) became the DAE Chief, although Bhabha himself did not live to see that.

Our hostel was at Land's End, Bandra. It was really Land's End! The road ended and the sea started. In between the end of the road (where there was a band stand) and the sea coast full of black rocks characteristic of the Bombay coastline, there stood rows of military barracks which had been in use during the second world war. Each building had a spartan simplicity: four walls mounted by a semi-cylindrical ceiling made of corrugated iron sheet. This was partitioned into two rooms and each room contained two trainees. This was the Training School hostel to be compared to the present sleek multi-storey building in Anushakthi Nagar.

The classes were held in the Churchgate area, either in the Jai Hind College or in the K C College. Some classes were also held in the new TIFR building that was coming up in the Holiday Camp (now called Navy Nagar). In fact I still remember cement and bricks falling through one part of the TIFR room when the lecture or tutorial was going on. So we commuted between Bandra and Churchgate.

The training school teachers came from BARC and TIFR. KK Gupta and Viswanathan taught Classical Mechanics. KS Singhwi and Anisur Rahman taught Quantum Mechanics, Gaurangh B Yodh taught Electricity and Magnetism, Ammiraju and Kondaiah taught Nuclear Physics, Babulal Saraf taught Kinetic Theory and Thermodynamics, MGK Menon taught Passage of Radiation through Matter, LS Kothari taught Solid State Physics, BM Udgaonkar taught Reactor Physics, MR Srinivasan taught Reactor Engineering. and George Abraham and R Narasimhan taught Mathematics. There were many other subjects like Electronics and Health Physics too. It was very impressive. I learnt a lot, much beyond what I learnt in the college.

Most of the teachers were excellent. We voted KK Gupta as the best teacher.

In our batch there were 50 + 50 + 50 trainees,in Physics, Chemistry and Engineering. There was no girl! Over the years, all this has changed.

There were many South Indians among us. We used to come to the hostel mess in dhoties. Ramanna passed an order disallowing dhoties. We went on a hunger strike. It

ended after a day; we capitulated after a day of starvation! I got first rank at the end of the training. For that I received the Homi Bhabha Gold medal from Prime Minister Manmohan Singh during the Golden Jubilee celebration of the Training School in 2007. But that was the second award for the same thing! Since I got not only first rank but my marks were way above those of the nearest to me, Colonel Ottley the hostel warden gifted me a book: "The man in the grey flannel suit". It was filmed in Hollywood with the famous actor Gregory Peck.

I got freedom to choose between TIFR and AEET for my research. All the trainees who were above a certain rank were allowed to choose BARC (called AEET at that time or TIFR). I chose TIFR.

Figure 2: Prime Minister Manmohan Singh presenting the Homi Bhabha gold medal, 2007.

Routes to Enlightenment!

Those of us who chose TIFR were taken to visit the experimental laboratories in TIFR. I found that all the laboratories were stacked with huge electronic boxes. Those days all electronic instruments used thermionic valves and hence were very big. I was thoroughly discouraged. I had a dread of electronics since my bad experience in MCC. So although I liked experimental physics, I had to do theoretical physics.

Tata Institute of Fundamental Research I (1958 to 1961)

But for theoretical physics also I had a problem. Theory needs maths in which I was poor. So when I went to see KS Singhvi, the head of the theory group, I told him that I wanted to do theoretical physics, but I am not sure since I was not good in maths. He said he does not know any mathematics! So I joined Theory.

A few trainees who joined Theory group in the early years were Sudhanshu Jha and K V L Sarma both from the first batch and Mukunda and Divakaran from the second batch. The atmosphere for study was very good and there was hardly any restriction on what we can do. There were occasional lectures and seminars which we attended.

Since my mind was bent on understanding physics at its most fundamental level, I first took up the study of Quantum Mechanics, since my knowledge of it was not strong. For any question that I asked, the answer was in Quantum Mechanics. I sat with L I Schiff's book for many months and mastered it. The other books I liked were PAM Dirac, the Bible of QM, Pauling and Wilson, an easy-to-understand book and Heitler, a very beautiful tiny book.

Then I turned to Nuclear Physics since that was the most fundamental subject at that time. I read Bethe and Morrison and then Blatt and Weisskopf. Went to Kailash Kumar and George Abraham for guidance. The former put me in contact with many

body theory and the latter in contact with few body problems. Abraham even suggested a specific problem. He asked me to redo the deuteron and triton structure using the recently discovered hard-core repulsion between nucleons.

I was not satisfied. I realized that the force between the nucleons comes from a deeper layer of reality which can be understood only from the then-new area called particle physics. There was no particle physics research in TIFR at that time. B M Udgaonkar (BMU) started studying hypernuclei which was in between nuclear and particle physics. Hypernuclei are nuclei in which one nucleon is replaced by a lambda particle. He introduced me to this subject and also to a few excellent reviews by Enrico Fermi on quantum theory of radiation and isospin symmetry.

He introduced me to Isospin and I calculated the ratio of Lambda going to $p + pi^-$ and $n + pi^0$ by using spurion technique. I thought it was a new result that I derived, but of course it was already well-known.

Udgaonkar was an excellent teacher. He had taught our batch of trainees reactor physics and the second batch quantum mechanics. Bhabha had sent him to France to learn about reactors, but BMU shifted to particle physics after returning.

Soon SN Biswas and LK Pandit joined and real particle physics started in the Theory Group. I started reading particle physics and learnt that the real theory of particle physics was Quantum Field Theory (QFT). So finally I reached the destination of my "Inward Bound" journey.

I took up Bethe and Schweber's QFT and Jauch and Rohrlich's Theory of Photons and Electrons. I really loved the systematic treatment of QFT in Wentzel's book. I took it during my vacation in Kamuthi and read it even during the long train journeys.

My learning of QFT was systematized and consolidated only after I listened to LK Pandit's course of lectures on QFT. I was so impressed by his excellent lectures that I felt I achieved "Enlightenment". I still remember lecturing to my friend Sudhanshu Jha on QFT during one of our evening walks along marine drive describing how I achieved my enlightenment. Maybe he was bored!

Soon I began to interact with Biswas and listened to his excellent lectures on integral equations. I was very impressed that an integral equation can be easily solved if the kernel is separable. Combining my knowledge of hypernuclei learnt from R H Dalitz's papers with a separable kernel as the potential between lambda and nucleon was very easy thing to do, with Biswas's guidance. Thus was born my first research paper and we proved Gell-Mann's Global Symmetry which simply equated all the eight meson-baryon coupling constants did not work.

Dallaporta visited TIFR and gave a series of lectures on the Symmetries of Hadrons. This was in 1960 before SU(3) came and he mainly talked about Gell-Mann's Global Symmetry. Gell-mann came to the correct SU(3) symmetry in 1961 only after many wrong attempts! Mukunda and myself took notes of Dallaporta's lectures that came out as a TIFR yellow report.

Heitler came and lectured on nonlocal QFT. Divakaran and myself took notes and brought it out as another TIFR report.

Gyan Mohan gave a beautiful series of lectures on QFT in Heisenberg picture and the LSZ form of the S matrix.

We were living in the servants' quarters attached to the Old Yacht Club where TIFR and AEET were situated, near Gate Way of India. This was the hostel of TIFR! One morning when I woke up, I was horrified to find that my finger-tips were of flesh colour. Mice had nibbled at them and removed flesh. They had done so with so much care that I was not awakened!

Bhabha had appointed an ex-ICS officer Mr EC Allardice, an Englishman, as the Deputy Director (Administration) of TIFR. Seminar notices were put on the notice boards only after he approved them. Once a notice about a seminar on "Odd-odd nuclei" was sent to him. Odd-odd, even-even, even-odd are technical terms in Nuclear Physics. Allardice said " These Indians! tunda-tunda pani, garam-garam chai". So saying, he cut off one "odd" from "Odd-odd" and sent it for the notice board!

I went on trekking in the western ghats with my friends who were senior to me: C S Warke, Biswarup Banerjee and K K Gupta. Once we were on a hill and I could see a long thing in a far-away hill moving. Obviously it was such a huge python which was visible from the next mountain!

On one such trip a funny thing happened. It was getting late and we wanted to take a short cut. One of us (KKG) suggested that we could cut the distance if we go through a railway tunnel. We were inside and it was dark. Suddenly we saw some light in the distance and we were happy that we were near the end of the tunnel. But the light grew bigger and bigger and we realized it was an approaching train! We were mortally afraid. It was a very narrow tunnel. There was space only for the railway track. All of us quickly hugged the tunnel wall. After the train passed, we thanked our stars and returned home, covered by soot and dust.

In those days, I used to see many films, sometimes more than one in a single day. English, Tamil, Hindi, even Marathi films! Those were really care-free days. There were two friends who were my constant companions. One was KG Nair a first batch trainee

who intruduced me to the pleasures of PG Wodehouse. The other was VS Arunachalam who later rose very high in the DAE hierarchy.

There was an euphoria in the air. Remember only a decade had passed since Independence and there was an expectation of great things. I felt "Nehru was in Delhi and Bhabha was in Bombay And all was well with our world". So my life and research would have gone on happily, but that was not to be.

One day Biswas told me that I must go to USA for PhD. I did not want to go; I did not think PhD was necessary for research. Those days PhD was a rarity. In MCC. Dr MA Thangaraj had great respect because of his doctorate degree, but most faculty members did not possess PhD degree. Also BMU in TIFR was not a PhD. But Biswas said that it was the policy of the Theory group to send young people for PhD. Biswas suggested that I should go to Maryland University. He liked Maryland University because JS Toll who had written some good papers on Dispersion Relations was there. He got the application form from Maryland. I was about to fill it when he came and said MGK Menon wanted to see me.

I went and saw him. He asked me why do I want to go to Maryland? I said I did not want to go, but Biswas asked me to go. He said I must go to Chicago University. He got the application form from Chicago and I filled it. Soon R H Dalitz was to visit TIFR and it was arranged that I must go to Chicago and work with Dalitz. TIFR packed me up and sent me! They bought the tickets, got the passport and visa.

Before that, I must describe what I call "The Bangalore Event". In the summer of 1961, the Summer School of TIFR was held at the campus of Indian Institute of Science, Bangalore. Gell-Mann and Dalitz were the lecturers and the audience consisted of students like me and many stalwarts like Homi Bhabha, MGK Menon, SN Biswas, LK Pandit, Virendra Gupta, Yash Pal and Alladi Ramakrishnan.

Gell-Mann lectured on his Eightfold Way version of Sakata's SU(3) theory, fresh from the anvil, even before publication. In Gell-Mann's Eightfold Way, proton, neutron and lambda were no longer a triplet, but a part of an octet.

During one of the lectures Dalitz asked him why was he ignoring the triplet which was needed to define the SU(3) symmetry. Gell-Mann evaded a direct answer in spite of Dalitz's repeated questioning.

If Gell-Mann had answered Dalitz's question, quarks would have been born there in Bangalore, instead of having to wait for another three years. If any of us had answered the question, that would have been a major Indian discovery. This was a missed opportunity.

Figure 3: Bangalore Summer School 1961 L to R: First row: Thunga (Alladi's student), Indumathi (Alladi's student),V Gupta, Yash Pal, Kharas (MGKM's secretary),MGK Menon, Gell-Mann, Bhabha, Dalitz, Alladi, Jallihal (Administrator), Radha (Alladi's student), Bhamathi, KK Gupta Second row: AP Balachandran, G Ramachandran, PP Divakaran (behind MGKM),GR (behind Bhabha), SN Biswas and LK Pandit (both between Alladi and Jallihal)

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I sailed from Bombay to Liverpool in UK in August 1961 and flew from London to Chicago. The ship journey in SS Caledonia of Anchor Lines took about two weeks stopping at Karachi, Port Sudan and then at Alexandria in the Suez Canal. We were allowed to land at all the ports and go into the city. At Port Sudan a few of us went to see a Hindi movie. On the way we met a Sudanese and asked him about the way to the theater. He looked at us, asked whether we are Indians. We said yes and he replied that he will not help us! While the ship was passing through the Suez Canal we made an in-land journey to Cairo and had a sight-seeing tour of the pyramids and the famous Cairo Museum.

I had planned to write the Candidacy Examination once I reached Chicago. So I spent the time in the ship preparing for that. I could revise whatever I knew in physics using the excellent book by Kompaneets which presented all of Physics in a capsule form.

University of Chicago (1961 to 1963)

On the first day at Chicago University I had a pleasant experience. I came out of the International House where I was staying and asked a gentleman about the direction to the place where the inaugural meeting for beginners was to be held. He said he was also going there. We walked together. Imagine my surprise that he went to the stage to preside over the meeting! He was Beadle, a Nobel-Prize winner in biology and the President of the University.

Soon I wrote the dreaded Candidacy Exam and passed. It was considered a tough exam and some of the questions were the ones set by Enrico Fermi. Generally students took one year to clear it. But I was not a beginner since I had spent four years in TIFR. I was admitted into the PhD programme and I was also Research Assistant to Prof Dalitz. Apart from Dalitz, there were many luminaries - Nambu, Oehme, Sakurai, Telegdi, Wentzel and Chandrasekhar. I attended the lectures by all of them.

I was staying at the International House and once I was returning after midnight after completing the experiment which everybody had to do in the course, I was accosted by a group of black boys who asked for money. Fortunately I had some money in my pocket. I threw it at them and ran for my life.

Another time a group of us went to a Cinema Theater beyond the Midway and we were surrounded by hoodlums again. We ran into a Department store.

Such events were common those days in the area where the University was situated. I hear things are much better nowadays.

Since I was a vegetarian, I suffered. Those days it was very difficult to get veg food in USA. At the International house the only veg food was half-boiled rice and half-boiled cabbage. Eating that day after day, I got sick of it. What saved me was the pizza. Once I discovered that, everyday evening I phoned Nicky's Pizzeria and ordered for pizza. From that time, pizza has remained my favourite food!

One day, when I was coming out of the library in the physics department, I saw Chandrasekhar emerging from the office. I realized that I was lucky to be in Chicago University. When I learnt that he was giving courses in General Theory of Relativity (GRT) and later, on Mathematical Physics, I took both courses. At the beginning of the GRT course, he said that he was teaching GRT since he wanted to learn it. He was absolutely right. Until then he had not worked in GRT. A few years after that he had mastered the subject and wrote his masterpiece "GRT and Black Holes". His Mathematical Physics Course was on generalized functions which he wanted to master and used it in studying

Black Holes.

Although I had attended two courses of Chandrasekhar, I hardly interacted with him. Chicago University had many Indian students. He had not interacted with any of them, as far I knew. Basically, he was a shy person. So imagine my surprise when one day, we got a letter from him inviting three of us A P Balachandran who had completed his Ph D in Madras and came to Chicago as a post-doc of Dalitz, R Ramachandran, a Ph D student and myself. He sent detailed instructions on the train that we must take to go from Chicago to Yerkes, some 70 km away. He had positions at Chicago University and Yerkes Observatory.

He came to receive us at Yerkes railway station and took us to his home. His wife Lalitha cooked a tasty South Indian meal for us. He took us around to see the telescope. We then played some ball game in his garden while he took rest. After a while tea was ready and we watched the TV. On that day Edward Teller was giving evidence in front of a Government Committee about the H-bomb programme of the Soviet Union. He became emotional and we could see tears from his eyes. Chandra talked to us about Teller. Then the conversation shifted towards other topics like particle physics, the subject of three of us and the science situation in India in which Chandra was greatly interested. We returned to Chicago with the satisfaction of spending a whole day in the company of a great man.

I take pride in the fact that I taught AK Ramanujam who later became a famous Kannada poet and translated Sangam Tamil poetry, some Tamil. At that time he was working as a research associate in the Department of South Asian Studies in the Chicago University. He felt that the Tamil I spoke was closer to the old Tamil since I come from the southern part of Tamil Nadu. He asked me to speak Tamil and recorded it. He paid me by the hour!

Dalitz asked me to make some calculations on hyper-nuclear physics. Although most of the main work was done by him, he included my name as a coauthor in the two published papers. I told him that I would like to work on a core topic of Particle Physics. He agreed.

At that time the dominant school of thought was the S matrix philosophy of GF Chew. Proving Mandelstam's double dispersion relations was considered the biggest challenge. Reinhard Oehme lectured to us on the many-sheeted S matrix,

AP Balachandran who had already obtained his PhD in Madras and joined as Dalitz's post-doc was frightening students like me by talking about the theory of many complex variables and "The Edge of the Wedge Theorem". He was very mathematically oriented.

Those days you either group or disperse. The former led to SU(3) group and the later led to Dispersion Relations. An interesting story about the proof of Dispersion Relations

from Field Theory is the following:

- Feynman: What is Dispersion Relation?
- Wigner: What is Field Theory?
- Chew: What is Proof?

Dalitz showed me a preprint by Oakes and Yang who criticized the SU(3) work of Gell-Mann and Neeman on two counts:

1. The decimet baryons Delta (1238), Sigma (1320), Cascade (1520) and Omega minus (1672) occur as poles of the S matrix on different Riemann sheets and so, no smooth movement of them is possible to give a single pole in the exact SU(3) limit.
2. The mass-differences in the octet and decimet of particles are so large that no perturbative treatment is possible for the symmetry-breaking interaction to yield the Gell-Mann - Okubo mass formulae for their masses.

I could immediately solve the first problem since I was already familiar with the different Riemann sheets of the S matrix, through the study of Oehme's papers. Solution was that there is a retinue of poles in different Riemann sheets corresponding to a single hadron. This was the discovery of what are now called "Shadow Poles".

But instead of sending off our result to Physical Review Letters as any American physicist would do, the conservative Dalitz sent a letter to Oakes and Yang. And Dalitz followed by me went away to Oxford. Meanwhile a host of other authors published the discovery of shadow poles. Dalitz and myself wrote up the result and published it in Physics Letters B later.

The second problem of Oakes and Yang did not have such a simple solution. It required detailed calculations based on models and that formed the core of my Ph D thesis.

Oxford University (1963 to 1964)

Dalitz decided to shift to Oxford University in 1963. Since my thesis work was almost complete, he gave me the choice of continuing at Chicago as his student or go to Oxford. I preferred the second choice and left Chicago.

I sailed from New York to London by the famous Queen Mary and completed the writing of my thesis in Oxford in 1964. Dalitz suggested that I must do post-doctoral work in some University in the USA, but I felt I must go back to TIFR since TIFR had sent me only for Ph D! So in the summer of 1964 I sailed from Marseilles to Bombay by SS Vietnam, a French ship.

I must describe the three types of ships in which I have traveled. Since TIFR paid for my journey from Bombay, I traveled in a first class ship SS Caledonia. There were no classes and everybody was treated as a first class passenger. In fact the captain dined with us. There were many interesting games in which I participated and even won a prize (Nehru's "Discovery of India")! Although Queen Mary was a famous ship, Dalitz's research funds could pay only for a second class ticket, myself being a student. The third journey from Marseilles to Bombay was paid from my pocket and so it was a French ship SS Vietnam used to carry Vietnamese prisoners of war! But there were many students returning to India in that ship and so I had a pleasant time. On the way, the ship stopped at Barcelona in Spain and we could do one-day sight-seeing.

Much later, when I was in California visiting my daughter Uma and her husband, they took me to visit Queen Mary which was anchored at Newport near Los Angeles. It had been converted into a Hotel. We stayed there and saw all the parts of the ship which were forbidden to me as a second class passenger of that ship 50 years ago!

During my stay in Oxford I enjoyed the company of Rajat Bhaduri and PP Divakaran, both second batch AEET trainees. Rajat got his PhD in Canada and came to work as Rudolf Pierl's post-doc. Divakaran, after spending one year at Chicago as Dalitz's student, came to Oxford like me. There was also ES Rajagopal, a condensed matter physicist working at Clarendon Laboratory at Oxford. Both Rajat and Rajagopal were married and we had very good food in their homes. Panchrathnam (before his name became famous as Panchratnam phase) was also a frequent visitor to Rajagopals' home, but was generally very quiet during our conversations.

While at Oxford, Dalitz sent me to attend the Varena Summer School at Lake Como, Italy. I attended the lectures of TD Lee, CS Wu, Martinus Veltman and many others.

Also, while at Oxford. Rajat and his wife Manjushree invited me to join them in a trip through Europe. Asish Datta, a friend of the Bhaduris, was the driver of the car that we hired and I was the map-guide. We visited France, Switzerland, Germany and Italy. It was an enjoyable trip.

Actually when I decided to leave for Bombay, I had not yet obtained my Ph D degree! Dalitz sent my thesis to my Ph D Committee in Chicago. Meanwhile I detected an error

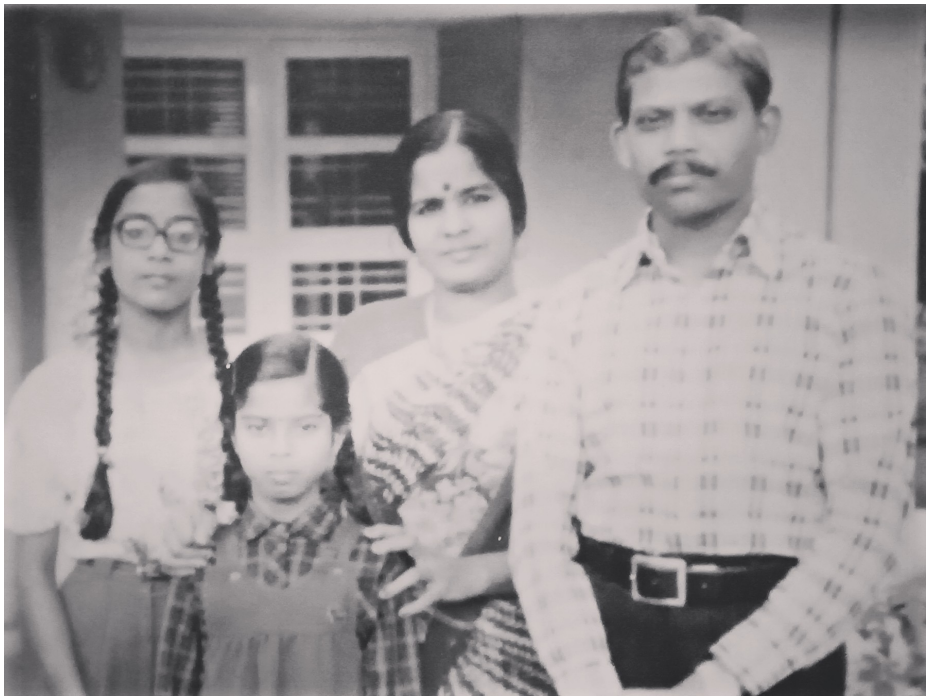

Figure 4: Circa 1982, Poongodhai, Uma, Suthandra, GR.

in my thesis and decided to recheck my calculations using the big computer in TIFR. It turned out that everything done using the computer at Oxford was correct and only some approximate calculation that I had tried in order to check my Oxford calculation was wrong! So the thesis was perfectly correct. I left for Kamuthi only after I made sure of that.

The thesis committee consisting of Telegdi, Oehme and a few others sent me the questions by post and I answered them by post. So my viva (the so-called third oral) was conducted by post. I passed it and in due time, Chicago University gave me the degree.

Back to TIFR ((1964-1976)

By 1964, TIFR had shifted to new buildings in Navy Nagar, Colaba from their temporary premises in Old Yacht Club near Gate Way of India. Bhabha planned the new building in such a grand scale that it is sometimes called the Tajmahal of Homi Jahangir Bhabha. We could work there in peace and comfort.

I married Suthandra Devi in 1965 soon after I returned from Oxford. Two daughters were born, Poongodhai in 1966 and Uma in 1972. Bhabha was killed when the plane

in which he travelled crashed against Mt Blanc in Switzerland. So an era came to end. MGK Menon took over as Director of TIFR.

Soon after I returned to TIFR, I started teaching graduate students, although the formal Graduate School started only in 1969. Many bright students had joined. Among them were Sriram Sastri, Ashok Raina, Dipan Ghosh, Kailash Rustagi and Vinod Sahni (from BARC) and many others.

Willis Lamb visited TIFR and gave many lectures on the recently discovered Mossbauer Effect. Biswarup Banerjee and myself took notes and brought out a TIFR report.

I went on a trip to the Himalayas with KKG, Biswarup and Luiz Balazs. Balazs was a theoretical physicist visiting TIFR. We went to Katmandu and from there we trekked. Our destination was the Valley of Flowers and Gosainkund Lake, which was sacred to Lord Vishnu. That was at 14,000 feet. After reaching 13,000 feet or so, we reached the snow-line and we could not climb further since we were not equipped for snow. Further we were told there were no shelters for the night. On previous nights we stayed in the huts of the villagers and finally in a cave. Beyond this point not even a cave would be there. The sherpa who accompanied us refused to go further. So we decided to turn back. But one of us, Balazs, refused. He said we cannot turn back without reaching our destination. In fact he was suffering from diarria and could not eat anything. He was the most frail among us. Still he was adamant and wanted to climb further. While we admired his courage and tenacity we did not want our trip to end in a tragedy. We forced him to return with us.

This Balazs is a tenacious character. He was well-known for his bootstrap calculations which was part of the S Matrix Theory. This theory was reigning over particle physics at that time. Udgaonkar and Virendra Singh were very much in it.

To begin with, I continued my research along lines connected to my PhD thesis research. I showed that the hadron Lambda (1405) cannot be a three-quark bound state, but it is a composite of a baryon and meson, the so-called "molecular hadron". I could construct a test for molecular hadrons. The test was simply that if it were a quark composite, the K matrix for meson-baryon scattering must have a pole but such a pole did not exist for K bar-N, pi-Sigma scattering. I talked about this result in two conferences, but did not publish in any journal.

I got into a controversy with my teacher Dalitz on the work on Lambda (1405), since earlier Dalitz, Wong and myself had worked on this hadron. Dalitz felt perhaps that he should be a coauthor in the K-pole paper. I wrote to him apologizing for what I did and explaining the circumstances in which this happened. Then I wrote a detailed paper

making due references to Dalitz's work and also thanking him.

Much later after QCD came up, it was shown that QCD also supports the conclusion that Lambda (1405) is not a three-quark bound state.

Meanwhile Gell-Mann's current algebra was making progress and I worked on Current Algebra for a while with L K Pandit and Virendra Gupta.

In 1970, the HEP Conference was held in Kiev, Russia. I was one of the delegates chosen by TIFR. They got the visa and bought the ticket. They brought them to me along with a form to be signed by me. I was supposed to sign a bond to work in TIFR for a certain number of years because TIFR was financing my trip. I refused to sign. I told Udgaonkar who was the Chairman of the Theoretical Physics Section that under the circumstances I would not go for the Conference. They said it was a mere formality, but I said I was against signing any bond, on principle. They wanted to consult the Director, MGK Menon. He was out of town, but on return, instead of coming to TIFR, he stayed in the Tata House! So I did not go to Russia. Looking back, the whole thing appears to be silly since I did not have any intention of leaving TIFR and so the bond was only a formality. I have described this event only because this is the only time I fought with TIFR. Because of this fight, TIFR removed the requirement of the bond subsequently!

Maybe as a consequence of this fight, I undertook a pilgrimage. I visited the temples at Kanchipuram, Thiruvannamalai, Srirangam, Kumbakonam, Chidambaram, Madurai, Srivilliputhur, Thiruvananthapuram and Suseendram. This was the first time I visited them except Madurai. I was truly amazed at the cultural magnificence of Tamil Nadu.

Kolar events :

One morning, my wife who was looking at the Times of India, exclaimed "Look, your friend KVL Sarma's name is in the front page!". I looked and found she had missed my name. The news item in the front page said G Rajasekaran and KVL Sarma have discovered a new particle. The Kolar experiments discovered some events that could not be explained. KVL Sarma and myself interpreted those events as due to a new particle. I also described this in an article in Physics News. TOI looked at only this popular science article and wrote the story. I was flabbergasted. There was no mention of the experimenters (that included MGK Menon). I contacted TOI and asked them to withdraw the story or at least correct it. They refused and said I can send a letter to the editor.

TOI could have verified the authenticity of their story by phoning TIFR. They didn't. This is the level of science reporting!

Recently at IMSc, MVN Murthy and myself have interpreted the 40-year old Kolar

events as due to Dark Matter particles.

Gauge Theory

I became aware of Yang-Mills (YM) theory by reading J J Sakurai's paper in Annals of Physics in 1959. That was the first paper in which YM was used in particle physics. Sakurai constructed a gauge theory of strong interactions. I continued to be interested in YM theory from that time. Veltman's lecture at Varena where he talked about the conserved weak current impressed me very much and I felt that weak interaction must be described by a YM theory. So, when Weinberg's paper on the SU(2)xU(1) electroweak theory came out in 1967 I had no doubt that was the correct theory. I read the papers of Goldstone, Higgs and Kibble.

In the subsequent two or three years, I lectured on these at various places including TIFR. In particular, in June 1971, I gave a series of lectures on the gauge theory of weak interactions including Yang-Mills theory, Faddeev-Popov ghosts, Higgs mechanism, electroweak theory, GIM mechanism etc. It came out as a SINP report. This was the first connected account of what became known as the Standard Model, anywhere in the world! It even contained my conjecture that the massless YM gauge quantum cannot exist as a particle because of the incurable infrared divergences (an early suggestion of what became known later as infrared slavery and colour confinement).

Nevertheless I failed to make any substantial contribution in gauge theory. This was partly because I had to take care of my sick father whom I had tried the treatments in the hospitals at Bombay and then in Madras, but to no avail. He passed away in May 1973.

I must refer to the peculiar circumstances under which I gave the gauge theory lectures at Saha Institute of Nuclear Physics (SINP) referred to above. In 1971, the whole of East Pakistan was in turmoil. Many refugees poured into Calcutta. Whole Calcutta was under siege. That is the time I went to SINP. Trilochan Pradhan who was my host made special arrangements for me. The driver who picked me up at the railway station was instructed to take a different route and take me to a different guest house. I was escorted with high security to SINP where my lectures were given. All over the City there were agitations and police shooting. Situation called for action by India. Indira Gandhi acted with a firm hand and Bangla Desh was born.

I became aware of t'Hooft's proof of the renormalizability of the electroweak theory which came out after my SINP lectures. Then came the discovery of asymptotic freedom of YM theory by Gross, Wilczek and Politzer and the construction of SU(3) colour gauge

theory by Gell-mann, Fritzche and Leutwyler to describe strong interactions.

Renormalizability of electroweak theory and asymptotic freedom of YM theory are the two most important discoveries in Quantum Field Theory after the discovery of renormalizability of Quantum Electrodynamics in 1947-49. I missed the boat in both, although I was well-placed with potential to contribute. I had already studied path integrals which t'Hooft used in his proof and was already giving lectures on Wilson's Renormalization Group and Callan-Symanzig equations which are the ingredients in the discovery of asymptotic freedom.

Although I missed the stage, I was sitting in the front row. I could catch their significance as soon as the discoveries came tumbling one after another! The years 1971-73 were truly exiting years. It was the watershed in the development of High Energy Physics.

Actually, until t'Hooft's proof, as far as I know, nobody except Joe Schechter in Syracuse University who added a U(1) to cancel the strangeness-changing neutral current and myself had taken Weinberg's theory seriously. Even after t'Hooft, only a few theorists took it seriously. Situation changed dramatically after the discovery of the weak neutral current interaction in the CERN experiment by Perkins and others in 1973.

In 1969, TIFR's theoretical physics summer school was at Nainital. Some memorable events took place there. Both Geoffrey Chew and Francis Low lectured. Chew lectured on S Matrix Theory. I asked him a question: Since S Matrix theory addressed only strong interactions, what happens to weak and electromagnetic interactions? Chew gazed at the distant Himalayan peaks visible through the window for a few minutes and simply continued his lecture.

Low lectured on the divergence problem of the Fermi theory of weak interaction and described all the methods proposed to deal with the problem. This was two years after Weinberg's paper. I asked Low at the end of his lectures why was he ignoring the Yang-Mills theory of weak interactions. He merely stared at me and refused to answer my question. He described seven or eight unnatural ways of solving the weak interaction problem but left out the one way that turned out to be the right way. To this day I have not understood how such a thing is possible, Low being a very experienced physicist. Somebody said it was because Low did not like Weinberg! Tapas Das and myself took notes of Low's lectures and brought it out as a TIFR yellow report.

Neutral Current

Weak neutral current (NC) interaction is almost as strong as the usual charged current (CC) weak interaction but lay undiscovered all those years. It could have been discovered many years earlier if only the experimenters did not listen to some theorists who said NC cannot exist. The theorists thought that NC would lead to strangeness changing NC decays which were not seen, but they forgot that there could be strangeness non-changing NC. So the experimenters ignored some data which were actually due to NC. But the clinching experimental proof was possible only after the huge Gargamelle bubble chamber was constructed at CERN. Because of its size they could clearly distinguish a pion from muon and this was crucial for the discovery of NC through the absence of muon in neutrino collision.

As soon as the discovery of NC was announced, KVL Sarma and myself produced the first model-independent analysis of deep inelastic data. JJ Sakurai called our equations "Master Equations". His analysis of elastic scattering coupled with LM Sehgal's of single pion production using the Master Equations led to the complete determination of NC coupling constants.

The evolution of the name starting from Gauge Theory is interesting. As soon as t'Hooft showed the renormalizability of electroweak theory I calculated the radiative correction to muon decay and sent it to Physical Review for publication. I had put the title as "Radiative correction to the muon decay in gauge theory". Physical Review changed it to "Weinberg's gauge theory". In 1972 the HEP Conference was held at Chicago that I attended. That is where gauge theory was presented as a Rapporteur's talk for the first time. BW Lee gave the talk. He called the theory as "Salam-Weinberg gauge theory". Salam and Gell-Mann were sitting in the first row and I happened to be sitting in the second row just behind Salam and Gell-Mann. As soon as Lee mentioned "Salam-Weinberg gauge theory", Gell-Mann gave a nudge to Salam with his elbow. Later when the Nobel Prize was given, Glashow's name was added and the theory became Glashow-Salam-Weinberg theory. This is certainly justified since Glashow was the first to discover that SU(2)xU(1) was the correct gauge group for electroweak theory and also he was one of the inventors of the Glashow-Iliopoulos-Maiani (GIM) mechanism to remove the strangeness changing neutral current. However I now prefer to call it the Electroweak Theory!

Integrally charged quarks

There is the possibility of quarks having integral charges unlike the Gell-Mann - Zweig (GZ) quarks which are fractionally charged. The former were introduced by Han and Nambu (HN). Probir Roy and myself constructed a colour gauge theory based on HN quarks and we got two interesting results. Although HN quarks have integral charges, as observed in deep inelastic scattering they will appear as fractionally charged. Further in this theory gluons are electrically charged and hence they also contribute to deep inelastic scattering. We published this in Pramana and soon we saw a preprint by Pati and Salam who also had the same theory. Although they also obtained the correct theory, they missed the fact that gluons in this theory are charged and hence contribute to deep-inelastic scattering. We pointed this out to them. Immediately Salam sent us a cable saying they were wrong and we were right. They also corrected their paper.

Subsequently, after I shifted to Madras, with my students and collaborators (T Jayaraman, Lakshmibala and Saurabh Rindani) I tested this theory by comparing the results with experimental data on deep inelastic scattering and electron-positron collisions. The theory agreed with data and could not be ruled out.

To this day this theory of HN quarks has not been ruled out by experiment and may even be the correct theory. Colour is broken in this theory spontaneously.

Visit to Hawaii

In 1974 my friend Sandip Pakvasa invited me to visit him at Hawaii University. Since I had two young children, I hesitated to undertake the travel. It was my friend C S Warke who said it would be a good opportunity for the family to see USA. I travelled with my wife and children. Spent two very interesting months in Hawaii and worked with Sandip. In October 1974, the earth-shaking news came. That came to be known as the psi particle later. At that time we only knew that some extraordinarily narrow peak had been seen in electron- postitron collisions. It was as if anthropologists stumbled upon a group of humans in some remote corner of the world who lived for 100,000 years! After that there was no peace! San Fu Tuan was constantly at the phone trying to get more information on the narrow peak from Stanford and other Centres. He, Sandip and me wrote up some dozen interpretations for the narrow peak and published it. This is one of the earliest papers on the subject. Fortunately we did include the one correct interpretation namely the psi particle was a bound state of a charmed quark and the corresponding antiquark.

After Hawaii, I took my family on a tour of mainland USA visiting UCLA, University of Texas at Austin, Rochester University, City College of New York, Maryland University and Syracuse University. In all these places I gave seminars.

How we proved three Nobel Laureates wrong!

1.By discovering the "shadow poles" Dalitz and myself proved CN Yang wrong.

2.By working out the Han-Nambu model correctly, Probir Roy and myself pointed out the error of Abdus Salam and Jogesh Pati.

3.After I returned to TIFR in 1964, the discovery of CP violation by Cronin and Fitch excited the particle physics world. During his visit in Caltech, Virendra Gupta (VG) published a paper in Physical Review Letters in which he had constructed what looked like an elegant model for CP violation. After his return to TIFR he discussed this with me and I discovered that his model violated CPT theorem and hence is not tenable. This was the shortest paper I ever published. Since in his paper VG had thanked Gell-Mann for discussions, he is the third Nobel Laureate I proved wrong!

I have to balance the above by the following.

My failed attempts

1.This was soon after I joined TIFR in 1958. In the primordial nucleon synthesis there was a gap. In the successive cooking of nuclei starting from proton by absorption of a neutron, there seemed to be a gap at A $= 5$ because He^5 is not bound. When I learnt that the hyper-nucleus Lambda-He^5 is bound, I thought that is the solution. I discussed it with Udgaonkar, but it did not work.

2.After CP violation was discovered from K decays into two pions in 1964, I thought the ugly CP violation can be avoided by recognizing that since pions are quark-antiquark bound states, Bose statistics for pions is only approximately valid and without Bose statistics, CP violation cannot concluded. This idea too did not work.

3.During 1964-64, with Arvind Kumar who joined me as a student, we undertook a massive calculation aiming to construct a complete theory of hypernuclei. In fact Arvind Kumar managed to do an enormous amount of calculation. It did not lead anywhere.

4.I tried to generate the nucleon-pion coupling using the quarks of which N and pi were made. This also did not lead anywhere.

5.For quite a long time,I imagined quarks to be leptons. That would have been the natural explanation for quarks and leptons satisfying the same current algebra. I tried to construct a mechanism by which the weakly interacting leptons could sometimes exhibit strong interactions, but I failed.

6. During 1967-70, I tried to construct strong interactions from weak interactions. by using the divergences of Fermi's weak interaction theory. TD Lee had shown how the quadratic divergences could be turned to strong interactions. Gell-Mann, Goldberger, Kroll and Ruderman wrote a nice paper showing how the quadratic divergences generate the diagonal (that is, the parity conserving strangeness conserving) sector that could be identified as the strong interactions. My aim was to redo these calculations using the YM theory of weak interactions of Weinberg's 1967 paper. But alas! t'Hooft proved the renormalizability of Weinberg's theory.

University of Madras (1976 to 1984)

Everything was going very well at Bombay. So why did I decide to leave Bombay? There are several reasons. For some time Shiva Sena was gaining ground. When there was water shortage, they even wanted to send back all Madarasis. One day there was a big agitation in the streets. When I was waiting at Gymkhana for the TIFR bus, some goons got hold of one of my TIFR colleagues and beat him up. So I decided that when a chance came I must leave Bombay. Second reason was that my children hardly knew Tamil and my wife spoke only Tamil. So I felt that my children must grow up in Tamil Nadu. A third reason was that I felt I must use my knowledge to teach at a University. Those were the days when Indira Gandhi introduced the slogan "Science for the People". B M Udgaonkar was advising that TIFR people must go to the universities to teach. But none of these is a strong reason. So I must attribute my shifting to Madras to fate!

First I was selected as a Professor at the Guindy Engineering College by VC Kulandaiswamy who was the Director of Technical Education at that time. Although the College was to be upgraded as the core of the Anna University to be formed, I felt it was not the proper job for a physicist.

I got a second chance when Madras University advertised for a Professorship in the Dept of Theoretical Physics. I applied and got the job even without an interview. But there were many difficulties. For one thing although the offer matched my basic salary, my total remuneration at the University was considerably lower than that at TIFR since at TIFR I was getting a large Dearness Allowance (DA) which was not available at the

University. Malcolm Adiseshaiah increased the salary considerably to match my salary plus DA at TIFR. I decided to accept the offer and joined Madras University in July 1976.

At TIFR I was living at the comfortable quarters provided by the Institute. At Madras I was literally thrown to the streets. I had to change the rented apartment three times until I finally managed to buy a old house.

A comparison between TIFR and Madras University would be apt at this point. I had figures to show that at TIFR, for every thousand rupees spent on salary for an academic person, ten times that much was spent on infrastructure, including library, money for attending conferences etc. In this I am not including the comfortable living quarters that TIFR provided. At the University, absolutely nothing beyond the bare salary.

Here I must mention my friend V Radhakrishnan who helped me on many occasions. But for him I would not have survived in Madras. He was a few years senior to me and I knew him and his wife Kaveri even at Bombay. He was a student of KK Gupta.

At Bombay, many were the evenings when he used to take me to Chembur, Sion or Matunga to listen to heavenly Carnatic Music by Chembai Vaidhyanatha Bhagavathar, Ariyakkudi, Semmangudi, MD Ramanathan or the celestial MS Subbulakshmi.

At the Dept of Theoretical Physics, there was PM Mathews who was the Head and G Bhamathi, M Seetharaman, MD Srinivas and SS Vasan were the faculty members. Malcolm Adiseshaiah introduced many rapid changes. He introduced MSc teaching at the Departments. Until then MSc was done only at the Colleges. The starting of MSc coincided with my joining. There were many good students. He introduced the semester system, monthly meetings of all professors with the VC and rotation of the headship of the departments. Since I was the seniormost after Mathews, I had to take up the headship.

There was V Srinivasan who joined as a visiting member. He was a remarkable person. He became a good friend of mine and we worked together on many papers. I took SD Rindani as a new faculty member and JK Bajaj and V Sriram as post-docs under my UGC project "Gauge Theory". T Jayaraman first and then Lakshmi bala who were MSc students became my PhD students. So we had a very active group.

During my stay in the University, the Department of Theoretical Physics was the venue for two activities. Bajaj wrote many papers on Grand Unification but got frustrated that the scale of that theory was far away from presently accessible energies. So he left Physics. Along with MD Srinivas and MS Sriram he founded a movement called Patriotic People-oriented Science and Technology (PPST) whose main theme was that unless we pay attention to Science and Technology done in India from ancient times, science will not take root in this country. They brought out a journal named PPST. The journal does not

exist any more. But the three of them founded the Centre for Policy Studies at Chennai and another institution in Delhi.

The Department= proved to be the venue where Sriram courted Lakshmibala and married her!

One morning an official car came to my residence to pick me up. It was because of a case against the University. I had conducted a meeting of a selection committee for a research assistant's post and made the selection. The former occupant of that post went to the court claiming he should have been selected. So the University sent me to meet the advocate of the University. That was P Chidambaram who later on became a Central Minister. Chidambaram asked me whether the person was selected by a regular selection committee on the basis of the academic qualifications of the candidate. I said "Yes" and he asked me to sign that as a written statement. I did so. Chidambaram said "Professor, I will now take care of it." That was that. The court decided in the University's favour.

Two bright students from IIT, Kanpur wrote to me saying they wanted to join me as research students. One was Avinash Dhar and the other was Ramadass. I think they were advised by my friends HS Mani and R Ramachandran, both at IITK. Avinash came. The University did not have any research fellowship money and no hostel facility. Avinash used his own money and managed to stay somewhere. He survived for a few weeks this way. Meanwhile he got admission into TIFR graduate school and I advised him to go. Because of this experience, when Ramadass wrote to me, I told him to go to TIFR. Both of them are now senior academicians at reputed institutions.

Malcolm decided to quit in 1979 and the University plunged back into its original state. All the measures that Malcolm introduced were undone one by one. MSc was stopped. I was getting frustrated.

Japan (1980 and 1981)

Advised by my friend Sandip Pakvasa, Hirotaka Sugawara of KEK Japan invited me. I went and spent two years (1980 and 81) there. KEK is the National Laboratory for High Energy Physics of Japan. Apart from Sugawara there were many other bright theorists such as Yoshimura and Kobayashi. I interacted with the experimental groups too. Yasumi, an experimental nuclear physicist who wanted to measure the mass of the antineutrino in the internal bremsstrahlung electron capture of Holmium asked me to join him as a theorist. I calculated the rate of this process. This was my only experimental paper.

I must say something about the Japanese physicists and students whom I encountered.

Their dedication and capacity for hard work were incredible. Even physicists in their sixties and seventies used to work in their rooms or laboratories very late into the night.

I had taken my family of wife and two daughters to Japan, but sent them back during my second year so that the school education of Poongodhai, my elder daughter was not affected too much. While in Japan both my daughters went to a Japanese school and picked up considerable Japanese.

I had many friends in Japan. Among them I must mention Roger Bissionnette who was an engineer in accelerator science. We used to travel together in Japan during my second year there.

In Japan I learnt three things: car-driving, Karate and Japanese language. Although I learnt to drive a car, I could not undergo the driving test since that required considerable knowledge of Japanese language. So I was driving only within the KEK campus! While learning Japanese, I found many remarkable similarities between it and Tamil. Of course all these three things that I learnt in Japan, quickly evaporated after return to India!

While I was at KEK, a memorial meeting for Tomonaga (who had passed away recently) was going to be held at Kyoto. All of us in the Theory group went to attend that. Schwinger was going to give the memorial speech. The announced title was "The two shakers of Physics". I thought the two shakers were Relativity and Quantum Mechanics. Schwinger pointed out that his Germanic name "Schwinger" meant "shaker" and "Shin" in the name of Shin Itiro Tomonaga also meant "to shake". So those are the two shakers! He gave an excellent speech telling us how Schwinger and Tomonaga developed QED sitting on either side of the Pacific, unknown to each other. It was war time and there was no communication. The parallel went further. Schwinger described how both independently developed the theory of wave guides and microwave cavities needed in war. Although the triplet Tomonaga, Schwinger and Feynman were involved in developing QED, Schwinger hardly mentioned Feynman. The only mention of Feynman was that Feynman missed the correct numerical factor in one of the higher order calculations!

I returned to Madras University in 1982 and was not happy. I felt sad that a lot of progress was taking place in High Energy Physics and I was stuck in this hole.

In 1982 I visited ICTP, Trieste. It happened that the W and Z bosons were discovered at CERN at that time. My friend Sandip Pakvasa informed me about the W discovery and I had the good fortune to convey that information to Abdus Salam when I met him. He was very happy and thanked me. All the time he was munching groundnuts!

At the ICTP canteen a few of us including a Pakistani physicist were discussing things and I mentioned the following. I said that Salam is the only scientist who could be the

Director of an Institution and at the same time made top-class discoveries. He discovered Superspace. I also said in a comparable situation Homi Bhabha had to abandon his research while managing TIFR and DAE. Immediately the Pakistani physicist said that is possible only if you can manage two wives!

Some interesting events

In 1963 I left Chicago for New York to take the ship for England. I wanted to visit my friend SV Rangaswamy at Philadelphia. At the New York bus station I was supposed to take the bus for Philadelphia. From inside the station I could see the bus about to start. I dashed for it, but was stopped with a loud crash. I had crashed into a glass wall. Immediately security men took care of me. My face and body were covered with broken glasses. The doctors attended on me and carefully removed the glass pieces from my eyes. They also treated the minor cuts. I was very much worried that I may have to pay for damaging the glass walls. I was told that it was the opposite; I can claim for the shock and injuries that I suffered. The glass wall did not have any lettering or other warning sign and so the bus station was liable to pay. But I did not want to make any claim. The security guards were with me and put me in the correct bus.

During my trip to USA in 1974 with my family we visited many Universities as I already described. I had bought air tickets for the whole trip involving New York, Hawaii, Los Angeles, Austin, Maryland, Syracuse and Rochester. At the Syracuse airport, at the check-in counter I was told that my ticket was not valid. We went on arguing, but the official did not allow us to board. Meanwhile my luggage was already put in the aircraft. I lost patience and shouted at the officials. I threw a tantrum that frightened everybody. But it worked. Since the plane had already left for Rochester, they put us in a tiny fore-seater plane. We reached Rochester and saw that our luggage was already waiting there.

When I was in Bombay, I traveled with Virendra Singh to attend the Conference on Few Body Problems organized by AN Mitra of Delhi University. We reached the airport very early in the morning. After checking in, we sat in the departure lounge and began our conversations. Our discussion was perhaps very interesting. We lost the sense of time and did not notice that departure of our plane was announced. After a while we noticed that we were the only two passengers sitting there. We saw through the glass door that our plane was in the runway. We ran past the security guards and when we were near the plane, the pilot saw us and began to move the plane. We ran after the taxiing plane. The

security guards took us inside the airport.

We complained that we missed the plane since the announcements were not audible ignoring the fact that they were audible to the other passengers! Finally they found two seats in the next plane, but we had to buy them. Fortunately V Singh had his cheque book. At Delhi, we missed only the morning session.

After returning to Bombay, we wrote to Indian Airlines asking for the refund of the fare that we had paid for the missed flight. There was no response. In spite of our repeated appeals, Indian Airlines refused to pay. We then had a bright idea. We had used the official letterhead of TIFR. This time we sent a copy of that letter to JRD Tata, the Chairman of the Governing Council of TIFR and also the boss of Indian Airlines. In a few days, we got our money!

I lived in the TIFR quarters at Chembur during 1967 to 1970 and commuted for four years. The quality of construction of the flat where we stayed was very bad. One day a big piece of the ceiling fell on the bed very near the place where my three-year old daughter Poongodai was sleeping. I met Bhandarkar the Administrative Officer at TIFR and demanded that I be allowed to occupy the Colaba quarters which were almost ready. He was making some excuses for the delay and I shouted at him right and left. This happened in the fourth floor of TIFR. He was a tall well-built man, but he simply ran for life, unable to bear my onslaught. I chased him until he disappeared into one of the rooms at the end.

It seems I was quite a terror those days!

As a consequence of this event, I was allowed to occupy the new flat in Colaba. I was the first occupant with many facilities not quite on. For instance the lift will close after we are in and take us to the basement where the door would not open. But that is another story.

Since both my daughters lived in the USA, every year we visited them. Once the immigration officer at Los Angeles airport saw that I had an invitation to visit the University of California at Riverside. He turned to me and said, "Since you are a Professor of Physics, I want to ask you a question. Is Einstein the greater scientist or Hawking?" I said, "Without question, Einstein!" He did not agree and we went on arguing for a while. Meanwhile he stamped my passport and I came out. Only when my daughter saw the passport, we realized the mistake. In my enthusiasm of argument I was not attentive and the officer stamped B2 visa. He was supposed to give B1, otherwise I cannot be paid by the University. My daughter Uma said it can be changed at the immigration office.

Early morning next day, Uma drove me for an hour from Redlands to the Los Angeles

immigration office where the line was long even that early. There were many Mexican immigrants whose entry is through Los Angeles. When my turn came, I told the officer about my problem. He said once the immigration officer at the port of entry stamps it, not even the President of United States can change it. I will have to go out of the country and while reentering I can change it.

Uma wanted to take me to the border town Tijuvana near San Diago. I was supposed to walk down and cross the border into Mexico and reenter. I vetoed the idea.

As an anticlimax, the secretary in the Physics Department paid me the money without looking at what was stamped in the passport.

Taking the plunge- The IMSc

I knew Alladi Ramakrishnan the director of the Institute of Mathematical Sciences (IMSc). I had many friends there and I used to stop over there on my way to Kamuthi and give seminars.

As I have already said Alladi was a good teacher. He was a Professor in the old physics department of Madras University. The department was headed by the famous GN Ramachandran. Through the help of C Subramaniam who contacted Nehru who contacted Bhabha, Alladi founded IMSc. It is not easy to found an Institute. Full credit for that goes to him.

But whatever he did after that was not creditable. Apart from inviting famous physicists who happened to pass through India, he did nothing. He did not recruit active young physicists. His autocratic way of running the Institute did not attract good people. The institute consisted mostly of his own students. Once DAE came to know his mode of functioning, they cut the funds which added to his woes. He did not conduct proper selection committee meetings. Once a selection committee was announced. A selection committee member was stranded at the airport. Alladi prevented the meeting from taking place, by not sending the vehicle to the airport.

Even the faculty who were hired, were hired for 6 months or 3 months. His mode of functioning became worse after his son completed his studies and became a mathematician. After that Alladi's one-point programme was centered around his son only. I was a member of a selection committee convened by Alladi. MS Narasimhan was the chairman and Alladi's son Krishnaswamy was one of the candidates. When it was the turn of the committee to examine Krishna's case, we expected Alladi who was a member of the committee to withdraw. But he did not. The Chairman had to ask him to withdraw!

In 1983 I heard that the Director of IMSc, Alladi, was getting superannuated and he had to quit. But I never considered going to IMSc since it was worse than the University. It would be like jumping from a sinking ship onto a sinking boat. I had good contact with Udgaonkar and I had a good conversation with him on IMSc when we were in the

same flight one day in 1983. A selection committee was set up to select the next director. Although I did not apply, the committee invited me for an interview. The Committee was chaired by V C Kulandaiswamy who had become the VC of the new Anna University. The other members were Udgaonkar and M S Narasimhan, the famous mathematician from TIFR. I went for the interview and I spoke frankly about the miserable state of IMSc and said if fresh blood could be infused, the Institute will survive.

I learnt that they had selected me. It was not clear to me whether I should be happy since I did not want to be an administrator although I did some administration as Head of the Dept in the University. I wanted to continue in physics.

Later I heard that ECG Sudarshan wanted to become Director and his friend Ramanna who was the Chairman of Atomic Energy Commission (AEC) decided to give the position to him. But apparently Sudarshan wanted also to hold his position in the University of Texas, Austin. So Ramanna wanted me to hold the fort at IMSc as a Deputy Director.

One day in 1983 I was informed that I must meet Ramanna. He was getting down from a military plane since he was the Defense Minister. I met him in the airfield itself. Ramanna said he had come only to meet me. Soon he was joined by Y S Das, the Additional Secretary. Both discussed the issue with me and tried to persuade me to accept the job. I was reluctant. The institute needed development and only a full-time Director can do it. How can I do it when the Director was sitting on the other side of the globe?

Later it seems that it was YS Das who solved the problem. Deputy Director cannot assume full powers. So they created the post of Joint Director and added this sentence in the constitution of IMSc: "During the Director's absence the Joint Director shall have full powers of the Director".

Even then I was not very happy. Many of my friends (Virendra Gupta of TIFR, Kameshwar Wali of Syracuse University) who knew Sudarshan better advised me against the move. I was happy that Sudarshan's presence in Madras would brighten the academic atmosphere. I would have preferred his full-time presence as the Director of IMSc and I could continue in Madras University. Since I knew him as a friend, myself and others in the Department could derive considerable academic benefits. But that was not to be.

I knew Sudarshan well. My relationship with him was very good based on the high regard I had for him because of his top-class scientific achievement.In 1974 He invited me and my family to Austin, Texas. We spent two weeks there and he treated us like a royal family. Later during one of his Bombay visits, my high opinion came down a little because of the derogatory words he uttered about Mahatma Gandhi. My regard for him

blinded me even to the wrong things about him that were said by others.

I got the appointment letter from the Tamil Nadu Government in October 1983. But could not take a decision one way or the other. Meanwhile there was considerable pressure from DAE. Finally in February 1984, I took the plunge. There were five months between my receipt of the appointment letter and my acceptance of the job.

I went to the Institute and took charge from TD Sundararaj who was the Education Secretary of Tamil Nadu Government and who was officiating as the Director of IMSc. Alladi tried to extend his tenure by six months or at least by one month. But the Government did not give him even one day extra and made sure that Alladi really quits by asking Sundararaj to sit in the Director's chair!

Building up IMSc (1984 to 1988)

Once I decided to take up the job, I plunged into it with full force and commitment. When I joined, there were only 12 faculty members and 6 students! Even after 20 years of existence the institute remained in the backwaters. Obviously recruitment was essential but that required many things to be done. Many developments had to take place. The following were taken up:

- Land for Hostel and Guest House,
- Central Government salary structure and other benefits,
- Recruitment of Faculty,
- Graduate School,
- MSc Programme (with Anna University),
- Theoretical Computer Science.

I will now describe how these were achieved.

When I see how hard it has become to get additional land for IMSc, I realize how lucky we were in 1984. Since my first priority was to recruit faculty at an all-India level and an vibrant Graduate School and an active visitors' programme, it was clear that the zeroth order step was to get land for the Hostel and Guest House.

Once I eyed the piece of land opposite to IMSc, where buffaloes were grazing, I determined to go ahead and get it. The fact that I had good relationship with both C

Aranganayakam who was the Education Minister of Tamil Nadu and the Chairman of our Governing Council and VC Kulandaiswamy who was the Director of Technical Education and a top Educationist, helped in the quick transfer of the land to us.

The salary-cum-allowance structure as well as other service benefits at IMSc were hardly such as to attract brilliant scientists to join here. I was keenly aware of the wide disparities that existed between IMSc and other national institutes where the salary structure was that of the Central Government.

In spite of many discussions and Committees that were set up, nothing tangible came out. At the end of my first year at IMSc, I was quite upset that we could not implement this measure which was a precondition for the success of our recruitment programme.

I decided to force the issue and worked out a strategy. I met Ramanna. He was sympathetic and appreciated the need for prompt action. He agreed to sign the letter (drafted by me) addressed to Aranganayakam. I carried the letter personally to the Minister and explained the situation to him. His approval was very prompt and I knew that day that the battle was won. I announced the improved service benefits to the Faculty immediately. This was the way the Gordian knot of Committees and Subcommittees was cut.

There were still some hitches. For instance the administrative and service staff was still not covered by the new scheme. I took our Registrar G Sethuraman with me to meet Ramanna at Kalpakkam to convince him of the advisability of enlarging the scheme to the administrative and service staff.

As a result of these endeavours, all the obstacles were removed and our recruitments started in full swing. Of course the benefits were applicable to everybody, whether new recruits or existing members. Every member of IMSc got a substantial increase in his or her pay with retrospective effect. Many other welfare measures available in other central government institutions such as Leave Travel Concession, Medical Scheme could be implemented in IMSc soon after, since all these were regarded as part of the same package.

Further, once the status of the IMSc members to be on par with others governed by the central government system was granted, then the subsequent improvements recommended by the Pay Revision Commissions became automatically applicable to our members. These benefits are enjoyed by all of us now, thanks to the government of Tamil Nadu and DAE.

During these four years (1984 to 1988), the faculty strength grew from 12 to 31. Both in Theoretical Physics and Mathematics we were able to attract very brilliant young people who became the pillars of IMSc in the subsequent years.

The close contacts that I had with various Centres in the country where good Theoretical Physics groups existed and similar contacts and even more importantly the stature that Seshadri enjoyed among mathematicians facilitated the recruitment programme. In fact most of the new faculty members in Theoretical Physics were known to me academically and all the new faculty members in Maths were known to Seshadri academically.

Along with the new faculty expansion, we recruited a large number of research students also. The total number of post-doctoral research fellows and research students increased from 6 to 35 in two years.

An important feature of the new recruitments must be stated and stressed here. In contrast to the original composition of IMSc before 1984 which consisted predominantly of members from a single state only, the newly recruited faculty and students hailed from various states spread all over the country. Thus IMSc achieved a truly national character.

Systematic post-MSc level courses for the research students working towards their Ph D degrees were started during this period, in all subjects coming under Theoretical Physics and Maths, since a sizeable number of students had joined as already mentioned.

Jagannathan and myself prepared detailed syllabi in all the subjects under Theoretical Physics. Jagannathan's keen interest in teaching and especially the meticulous care to detail that characterized all his work played a major role in putting the teaching of theoretical physics on a sound track. We thus laid the foundation for the Graduate School at IMSc that has flourished over the years.

From early on, it was clear to me that there was a serious gap in our graduate school. Although the School was primarily intended for post-MSc students, we had allowed "exceptionally bright" post-BSc candidates also to apply. In fact there were a few who had only BSc, but were better than the best post-MSc students. It seemed a pity to send them back to college for another two years for getting an MSc degree.

I discussed this problem with VC Kulandaiswamy who had become the VC of the newly created Anna University. He had also appointed me as member of the Syndicate, Academic Council and the Board of Studies of the University.

He understood the issue and agreed to introduce a new degree called MSc (by research) in the University that can be run by IMSc faculty in collaboration with Anna University. Since I had been inducted into all University bodies it was possible for me to discuss with members of all of them and get the new degree approved.

This is how MSc started at IMSc and it functioned as a door to introduce "exceptionally bright" candidates into research, just after their BSc degree.

Starting of Theoretical Computer Science Research is another milestone in the growth

of the Institute during 1984-88. In the pre-1984 period there was no Theoretical Computer Science group in IMSc. Such a group was formed after PS Thiagarajan joined IMSc in 1986. Soon other younger members joined and a strong TCS group has been flourishing at the institute.

Although I had full powers I knew about Sudarshan's ego. So I made it a point to discuss with him when he came after his stay in Texas, all the important steps taken by me and got them signed by him. In the beginning things went on smoothly. In fact many times he told me "Rajasekaran, we seem to be thinking along the same lines!"

But as the years went by, things changed.

Turmoil(1989)

Sudarshan spent less and less time at IMSc during the four years 84-88. Every year he spent half the year in Austin, Texas. Some years it was more. This would not have mattered much if the Joint Director had been allowed to function with full power. But Sudarshan's ego prevented that. Slowly he began to dislike everything I had done in his absence. He would come after a long break and make decisions inconsistent with what was done in his absence.

More importantly, selection of faculty was being held up. It was very difficult to have Selection Committee meetings during the period of his brief presence since other members who were busy could not come on those days.

Especially in Mathematics this became a serious issue. Seshadri insisted that I must act since I had the authority. So I conducted a Selection Committee meeting in Sudarshan's absence. M R Srinivasan was in the chair. I sent out the appointment letters. When Sudarshan learnt about this he was furious. I told him it was a duly appointed selection committee and I had authority to hold its meeting.

One of the candidates selected was V S Sundar, a mathematician. He joined. Sudarshan called him to his office and told him point-blank that he must quit since his appointment is cancelled. This must be an unprecedented behavior by the Director of any institution. Sundar left and rejoined only after Sudarshan was removed. He has done high-quality mathematics ever since.

IMSc had one faculty member representing the faculty in the Governing Council. So far KR Unni, was doing that and his term ended. Whom to appoint now? Earlier I think Alladi simply did it by fiat. I thought of doing it more rationally. There were two candidates, ND Haridass and Seshadri. Although I preferred Seshadri I decided there shall

be an election. Seshadri was chosen unanimously. That also angered Sudarshan.

I must say something more about Seshadri here. From the beginning it was clear that Seshadri, being an eminent mathematician and involved in the actual recruitment of mathematical faculty in IMSc, must be made in-charge of the Maths group. This simple thing was resisted by Sudarshan. He wanted to play politics between Unni and Seshadri by not announcing that Seshadri was in-charge of the maths group.

Meanwhile Seshadri became FRS. It became a glaring injustice not to make him in-charge of the Maths group.

As for my relations with Alladi, in the beginning they were cordial. In fact after hearing that I was to take over, he threw a party to welcome me! The relationship got soured only because of his son. Krishna, while being on the rolls of IMSc as a faculty member, was almost permanently abroad. Once when his application for extending his leave came to me as the director-in-charge, I refused. Alladi himself phoned me repeatedly asking me to grant his son's application. I had to cut him short. From that time Alladi treated me as his enemy.

All these things accumulated increasing the tension in the Institute. But the event that toppled the apple cart is the dismissal of Sethuraman, our registrar. In the beginning years at IMSc I had struggled with the administration and I felt that a competent registrar is necessary. I went to Ramanna for help. He sent G Sethuraman from DAE as our registrar. I knew him since earlier he was the typist cum secretary in the Theoretical Section of TIFR. In fact many of my papers intended for publication were typed by him. He turned out to be an excellent registrar having good liaison with DAE.

Above all Sethuraman had unquestionable integrity. So he did not like some of the money dealings of Sudarshan which were shady and apparently will involve the institute also. Sethuraman expressed his misgivings to Sudarshan. The later dismissed the former unceremoniously without giving any reason.

That was too much. I had to act. I sent a detailed report to M R Srinivasan who was the Chairman of the Governing Council (GOC) with copies to all the members. In the main I mentioned the continued absence of Sudarshan for months together and his erratic actions when he comes. I said I cannot hold the fort under these circumstances. Actually this is the first time that the GOC became aware of Sudarshan's absence from IMSc for long periods.

Sudarshan's reaction was violent and became more erratic. He cut off my official phone connection. He gave a kick to the door of my office room and removed my name plate.

I felt even my life to be in danger and wanted to be away from Madras. Both IIT Kanpur and IIT Bombay offered me refuge. The former sent me the appointment letter. Finally I decided to go to TIFR, vowing to return only after Sudarshan was removed. TIFR was a familiar place for me. Also I could watch what DAE was going to do.

In this struggle, most of the faculty supported me. In particular, there were Haridass, Baskaran, Thiagarajan and Balasubramaniam who were with me. Of course Seshadri was with me. Only the faculty who joined before 1984 did not support because of their alleged loyalty to authority.

Thanks to TIFR I enjoyed peace for one year (1989). There I could return to Physics and complete some of the research projects.

Finally Sudarshan left at the end of 1989. He had to leave since his 5-year term ended. But he went to the court against the institute claiming he was a permanent director. He quoted some statement of Indira Gandhi the Prime Minister as evidence. But he had signed a 5-year contract. He tried to hide that, but Sethuraman managed to unearth it and the judge threw that at his face and dismissed the case. Of course all this took time.

My sufferings were not over. He filed a criminal case against me citing the official letter I had written to the GOC as defamation. I had to fight it out. My lawyer told me that according to Indian law, if you call me a fool it it is not defamation if you can prove it. So the lawyer asked the court to ask Sudarshan to produce his passport which will prove his absence. His lawyer went on asking for postponement for many months. My lawyer had advised me to be present whenever my case came up. His lawyer did not appear at all. So finally the judge dismissed the case.

All this took time, also money. Sudarshan could throw away a few dollars at his lawyer, but in my case it was my hard-earned money. Later IMSc offered to reimburse this expense, but I was not keen. Sudarshan's aim was only to torture me and he succeeded.

Let me mention two unexpected fall-outs from the turmoil.

Prof Seshadri left IMSc with a group of Maths and TCS people and founded what became known as CMI (Chennai Mathematical Institute). Thus a good thing can emerge from a bad happening!

A very strong group of high-energy-physicists, Anjan Joshipura, Saurabh Rindani and Utpal Sarkar, whom I had hired left IMSc during the turmoil and founded the HEP group at the Physical Research Laboratory (PRL),Ahmadabad. What was a loss for IMSc became a gain for PRL!

Back to peace and progress (1990-now)

The Institute was put back on the path of progress in 1990. R Ramachandran took over as Director in 1990 and IMSc had a smooth sail after that. Thanks to him I could get back to academic activity. During his term and after Balasubramaniyam took over in 2000, the institute continued to grow and has reached great heights. Progress continues with the present Director V Arvind.

The following event might have happened in 2011 when the Golden Jubilee of IMSc was celebrated. The famous physicist David Gross who is a Nobel Laureate visited the Institute and went to Kolkata. I was also going to Kolkata and so we traveled together. His wife was with him. At the Chennai airport he wanted to wait at the VIP's lounge and wanted me also to be with him. In the lounge, there was Amartya Sen, another Nobel Laureate with his wife. Gross and Sen knew each other. So, for a while I was enjoying the company of two Nobel laureates!

But the story does not end there. After the plane took off, Gross came to me running and said "Rajaji, I lost my laptop in the airport." At the security check-up he forgot to pick it up. Although the laptop was an expensive one, he was particularly worried since he had many valuable documents in that laptop. After we landed, from the Kolkata airport people it was difficult to get any help. Fortunately my friend R Simon from IMSc happened to have arrived at Kolkata airport at the same time. With his authoritative voice and gestures, he forced the airport people to make the connection to the Chennai airport. We got the news that the laptop is safe and will be sent to Gross at USA. Gross did receive it in due time.

Figure 5: L to R: Rajat Bhaduri, Suthandra, GR, Manju Bhaduri, Poongodhai. Below: MVN Murthy, Uma.

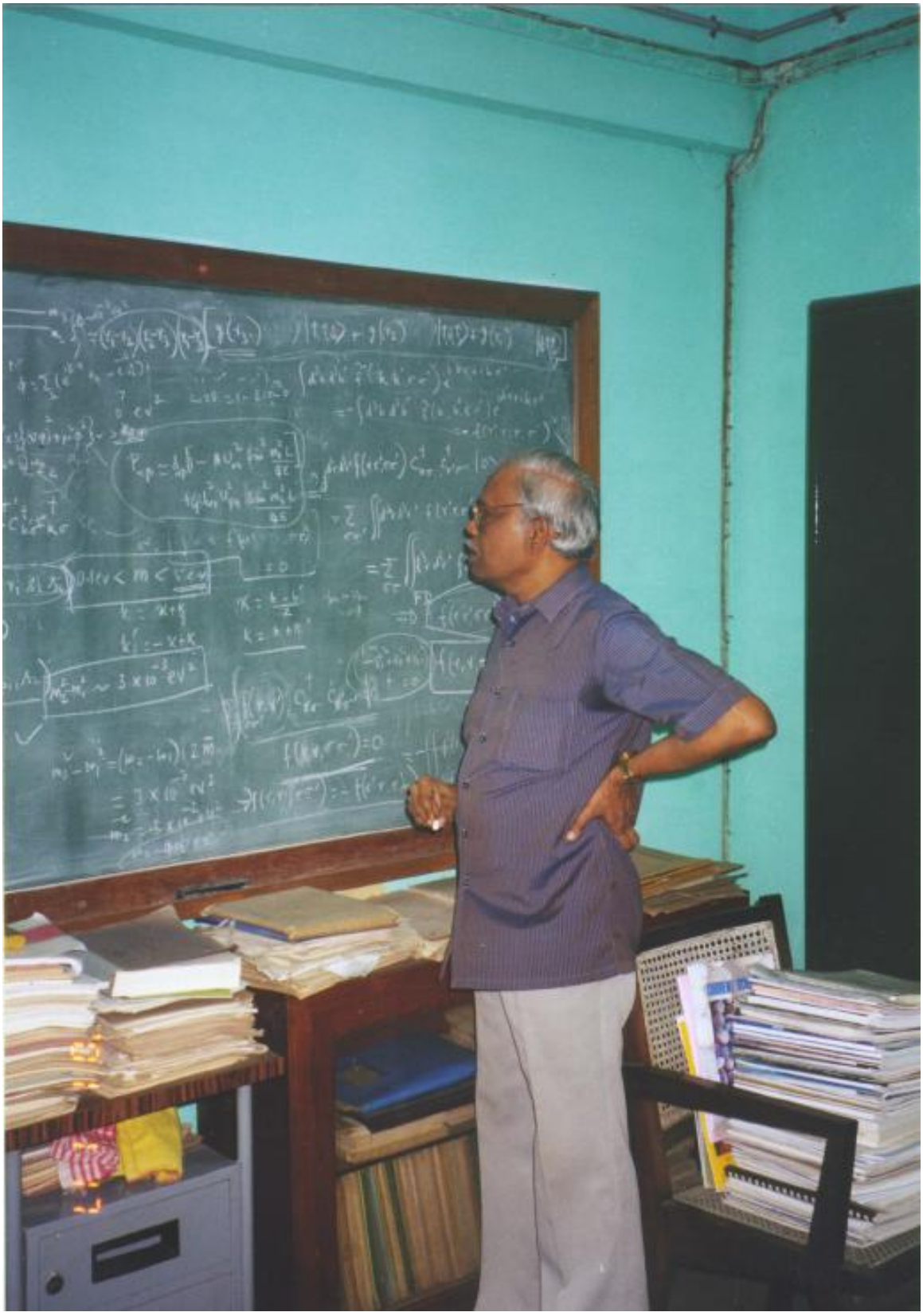

Figure 6: At the blackboard in my old office.

Other Activities and Research

Chennai Mathematical Institute (CMI)

Seshadri founded CMI with Mathematics and Theoretical Computer Science. Even before IISERs came, Seshadri admitted into CMI talented students after school so that they can pursue their studies in an atmosphere of research. He wanted CMI to grow into a full-fledged University and as a first step wanted to have Physics. He asked me to help in Physics Faculty recruitment and teaching. I have been doing that. We now have a Theoretical Physics Group of outstanding young faculty members.

Figure 7: Receiving the A C Banerjee Memorial Award of The National Academy of Sciences from C S Seshadri, Director CMI.

Some of the other institutions in whose development I played a role as a member of their Governing Council or other bodies are Harishchandra Research Institute, Institute

of Physics, Saha Institute of Nuclear Physics, Inter-University Centre for Astronomy and Astrophysics, SN Bose Centre for Basic Sciences, Indian Institute of Astrophysics and Astronomy and IISER, Thiruvananthapuram.

Teaching

Apart from teaching full courses at CMI, I have been involved in considerable teaching in other Centres too. Academies-organized Refresher Courses in many Colleges in Tamil Nadu, Kerala and Karnataka took up a lot of my time and energy. For many of them I was the Director. Sunday Classes (venue: Dept of Nuclear Physics of the University) were started by Satyanarayana of Pondicherry University with the help of Joseph Prabagar of Loyola College. I joined the team and taught. I was involved in the running and teaching in the DST-organized SERC Schools in Theoretical High Energy Physics for more than ten years and I initiated the Physics Teaching for Talented Students. Courses in High Energy Physics were given by me at IISER-Thiruvananthapuram, IISER-Mohali, Banares Hindu University Madurai Kamaraj University and many other institutions.

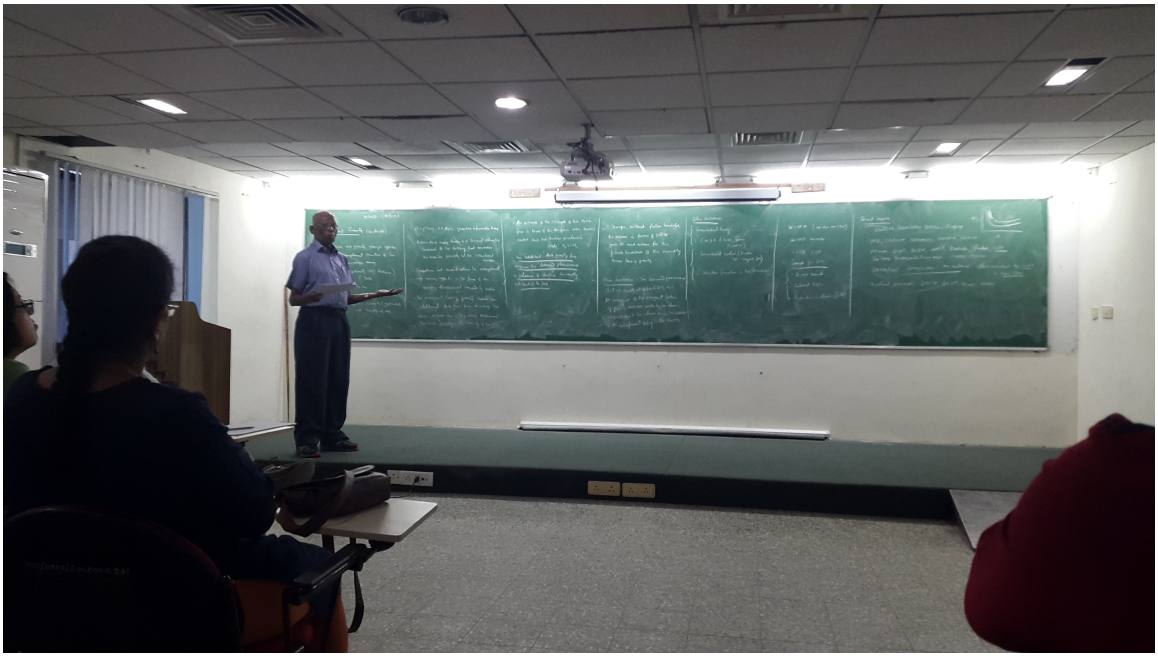

Figure 8: Lecturing at IMSc.

Popular Science

I strongly believe that Popular Science will succeed in the country only if it is done in the mother tongue of the people. My ambition to write Science in Tamil fructified through the kindness of my friend Dr Jeyapragasam who was the Editor of a Tamil monthly published from Madurai. I wrote every month and brought out two volumes containing my articles.

Figure 9: At one of the Academy's Refresher School.

New Forms of Quantum Statistics

AK Mishra and myself discovered many new forms of quantum statistics during the period 1990 to 95. This was possible because of the Generalized Fock Space that we constructed. Some of the new forms of statistics were Orthostatistics, Null Statistics and Hubbard Statistics. Along with this we constructed many new algebras of creation and destruction operators. Many of these are expected to be used in future, in String Theory and other fundamental theories.

String Theory and LPA

I was aware of String Theory almost from its birth. When I was perusing the preprint library in KEK, Japan in 1980 I saw the paper of Scherk and Shwartz who liberated String Theory from its hadronic context by changing the string tension from 1 GeV to 10^{19} GeV. That was the birth of String Theory. Then in 1984 I was escorting Tullio Regge from Bangalore to Madras and he told me the exciting discovery made by Green and Schwarz that all the anomalies cancel in the SO(32) and $E_8 \times E_8$ Superstring theories.

From then on I learnt whatever was known in String Theory and gave lectures on it in various Conferences, Workshops and the SERC School. But because of the heavy work involved in the building up of IMSc (1984-88) and the turmoil in 1989, I could not work in String Theory. But I kept up my interest in it because I believe that is the Theory for Future incorporating Standard Model and Quantum Gravity.

The main difficulty of String Theory is the lack of experimental support. That requires construction of accelerators going up to Plank energy 10^{19} GeV. Many regard that as impossible. This is a crisis in Physics. But human ingenuity knows no bounds and this energy barrier will be crossed. New principles of acceleration will be discovered. I have been emphasizing this for the last 40 years. Laser Plasma Acceleration (LPA) is one such and it has been pursued for some time all over the world. I have discussed the importance of starting LPA with experts on lasers at TIFR, Raja Ramanna Centre for Advanced Technology, Institute for Plasma Research and BARC. All of them met at the International Centre for Theoretical Sciences and they are chalking out a plan of action.

In the 80's I had many discussions with CVK Baba and MVN Murthy about building an accelerator of energy in the 5 to 10 GeV in India. DAE was willing to support it, but there was no enthusiasm among the experimental high energy physicists. They said such an accelerator would be useless unless it is more than 100 GeV. After this debate of ours, China built the Beijing storage ring of about 3 GeV which made many important contributions including a more precise measurement of tau mass which cleared many existing discrepancies.

Finally INDUS I and II were built after much delay but they were for synchrotron radiation.

Anyway, it is time that we now think of new methods of acceleration such as Laser Plasma Acceleration.

The contrast between the Indian situation pre-1971 and post-1984

The success of the Standard Model based on YM theory has made YM a bandwagon. But I am talking about the pre-1971 era. As I already mentioned, I was lecturing on YM and electroweak theory in TIFR, SINP much before these things became popular, even before t'Hooft proved the renormalizability of YM with SBS. But there were no takers.

I remember, for instance, when I derived that in YM theory of weak and electromagnetic interactions the weak bosons have masses greater than 37.4 GeV, many people jumped on my neck saying " How can you put zero-mass photon and such heavy bosons in the same multiplet?". Times have changed. Now one routinely puts essentially "zero-mass" particles and their superpartners, of TeV mass or even heavier, in the same supermultiplet.

When string theory came in 1984, there had arisen a sufficiently large number of capable young Indian physicists, both inside and outside the country who could pick up the new ideas fast and contribute at the front level.

It is clear that theoretical HEP in India has made rapid strides and now our theorists are equal to the best in the world.

Neutrinos

Neutrino oscillations and neutrino mass were discovered during 1996-2002. I was excited about Neutrino oscillations after I read about Mikheyev, Smirnow, Wolfenstein (MSW) effect in Bethe's PRL paper in 1986, that gave a beautiful explanation of MSW effect as a consequence of level crossing, during my visit to Hawaii in 1986. I conveyed that excitement to Anjan Joshipura and M V N Murthy who then wrote the first paper on three neutrino resonance phenomenon.

During the nineties, MVN Murthy, D Indumathi, S Umasankar, Mohan Narayan and myself did considerable amount of work on neutrino phenomenology. We were the first to analyze all the neutrino data in a three-neutrino framework instead of the toy model using two neutrinos that was used until then. We were the first to analyze the null result of the CHOOSE reactor experiment on the basis of the three-neutrino framework and get an upper bound on the θ_{31} angle to be 12 degrees. Later experiments showed this angle to be 9 degrees, close to our upper bound.

I also worked on models of neutrino masses and mixing in collaboration with Ernest

Ma of the University of California, Riverside. One of the models that we constructed, the A_4 model, became quite popular.

In collaboration with MK Parida and Rabi Mohapatra, I discovered the real reason for the neutrino mixing angles to be different from the quark mixing angles and so large. It is the renormalization group evolution. Both the leptonic and quark mixing angles are of the Wolfenstein form at high scale and the leptonic angles alone get magnified at low scale.

Raju Raghavan

Raju Raghavan was a great experimental physicist. Although I knew him earlier since he was a second batch trainee, we became friends only after I came to Madras. He used to visit me whenever he came from USA and we discussed neutrinos. He had many original ideas on neutrino detection, including Mossbauer resonance absorption and emission of neutrinos. If one succeeds in this, neutrino experiments can be done on a table-top!

Later, after INO was conceived he was its enthusiastic promoter. He had conceived a detector of solar low energy neutrinos, called LENS (Low Energy Neutrino Spectrometer) which can revolutionize solar neutrino physics. He wanted to do the experiment in India. I took him to meet the secretaries of DAE and DST and they agreed to support him.

But Raghavan passed away suddenly in 2011. I was shocked and took a long time to recover. Actually at that moment when I heard the news, I was arranging a major meeting of Raghavan with scientists and science administrators. His death is a serious loss to Indian Science. India must take up the LENS Project.

India-based Neutrino Observatory (INO)

India was a pioneer in neutrino experiments. The very first observation of cosmic ray produced neutrinos called atmospheric neutrinos was made in India, in the Kolar Gold Field (KGF) mines. That was in 1965. But the mines were closed in the 90's. Since there was not much gold, the Bharath Gold Mines company decided to close it. We should not have let that happen. "Science is more precious than gold."

When the issue of possible closure of the KGF mines came up, I argued in favour of keeping them alive for future underground experiments. I raised it in many meetings. In the DST meeting on Thrust Areas held at Santiniketan, MVN Murthy presented both the issues, the case for keeping the KGF and construction of an accelerator for HEP.

It was neccessary to spend some money for keeping the water in the mines out by pumping. But that is negligible compared to the cost of digging new tunnels. If this had been done, there would have been a continuity in Indian neutrino experiments from Kolar to INO.

It is the atmospheric neutrinos which in the hands of the Japanese physicists enabled them to get two Nobel Prizes, in 1998 and 2002. We clearly missed the boat.

Can we recover this lost initiative? We can and we must. The INO was conceived with this aim in view.

It was conceived in IMSc in the year 2001, but it has not still seen the light. It was approved by all the Central Government bodies and the Government granted Rs 1600 crores for the project. This involves the construction of a 50,000 ton magnetised iron calorimeter detector for atmospheric neutrino studies. This will be installed inside a mountain in Theni District. The nerve-centre of INO will be in the outskirts of Madurai City and will house R and D of particle detectors with training facilities for students. This has been named Inter-Institutional Centre for High Energy Physics (IICHEP). Apart from

Figure 10: At the site in Theni District chosen for INO.

the study of atmospheric neutrino oscillations, INO lab will house experiments searching for Neutrinoless Double Beta Decay (NDBD) and Dark Matter (DM). CVK Baba and myself played some role in initiating the NDBD activity. As a consequence two or three groups involving Vandana Nanal, RG Pillay, PK Raina and PK Rath are involved in feasibility

studies for the NDBD project. I tried to initiate work on Dark Matter Search through Rupak Mohapatra of Texas A and M and physicists at SINP. This could have been a major project but it did not succeed. Instead a minor Dark Matter project at a shallow depth in the Jaduguda mines has been started.

Along with others I have lectured on INO to students in colleges and schools and villagers as a part of of the INO's outreach programme. This is continuing.

Some "wise men" of Tamil Nadu blocked INO citing non-existent environmental and other imaginary dangers. This obscurantist propaganda must be fought and INO must succeed. Truth has to triumph.

Family

I have been blessed with a loving family - Suthandra Devi (my wife), Poongodhai and Uma (my daughters), Sunil Ramachandran (Poongodhai's husband), James Harano, (Uma's husband), Anjali and Shalini (Poongodhai's daughters) and Kailash (Uma's son). Along with my family there are many friends who supported me, too numerous to mention by name.

Figure 11: Circa 2017 L to R: James, Uma, Poongodhai, Kailash, GR, Shalini, Suthandra, Anjali, Sunil.

Part II: My Scientific Autobiography

My Scientific Autobiography

The Beginning :

A crucial event occured when I was in the Intermediate class of the Amercan College, Madurai. A friend of mine took me to observe the night sky through the College telescope.

It was the best time to observe the Moon since the shadows of the mountains were long. When I saw the deep craters and high mountains, it was as if I was looking down at the Moon from a height. It was a frightening sight. I realized that

There are more things in heaven and earth than are dreamt of in my philosophy.

Science is the key to these other things and that determined my trajectory in life.

Preparation :

I joined TIFR in August 1958 after one year in the AEET(BARC,now) Training School. Since my mind was bent on understanding physics at its most fundamental level, I first took up the study of Quantum Mechanics, since my knowledge of it was not strong. For any question that I asked, the answer was in Quantum Mechanics. I sat with LI Schiff's book on Quantum Mechanics for many months and mastered it.

Then I turned to Nuclear Physics since that was the most fundamental subject at that time. I read Bethe and Morrison and then Blatt and Weisskopf. Went to Kailash Kumar and George Abraham for guidance. The former put me in contact with many body theory and the latter in contact with few body problems. Abraham even suggested a specific problem. He asked me to redo the deuteron and triton structure using the recently discovered hard-core repulsion between nucleons.

I was not satisfied. I realized that the force between the nucleons comes from a deeper layer of reality which can be understood only from the then-new area called particle physics. There was no particle physics research in TIFR at that time. B M Udgaonkar (BMU) started studying hepernuclei which was in between nuclear and particle physics. Hepernuclei are nuclei in which one nucleon is replaced by a lambda particle. He introduced me to this subject and also to a few excellent reviews by Enrico Fermi on quantum theory

of radiation and isospin symmetry. Udgaonkar was an excellent teacher. He had taught our batch of trainees reactor physics and the second batch quantum mechanics. Bhabha had sent him to France to learn about reactors, but BMU shifted to particle physics after returning.

Soon SN Biswas and LK Pandit joined and real particle physics started in the Theory Group. I started reading particle physics and learnt that the real theory of particle physics was Quantum Field Theory (QFT). So finally I reached the destination of my "Inward Bound" journey.

I took up Bethe and Schweber's QFT and Jauch and Rohrlich's Theory of Photons and Electrons. I really loved the systematic treatment of QFT in Wentzel's book. I took it during my vacation in Kamuthi and read it even during the long train journeys.

My learning of QFT was systematized and consolidated only after I listened to LK Pandit's course of lectures on QFT. I was so impressed by his excellent lectures that I felt I achieved "Enlightenment".

Soon I began to interact with Biswas.

I will divide the account of my work into two parts; Pre-Standard Model and Post-Standard Model. The numbers here refer to the list of publications at the end.

Pre-Standard Model

This can be subdivided into three parts, Hypernuclear Physics, SU(3) and Hadronic Resonances and Current Algebra.

Hypernuclear Physics :

My first paper [1] was in this field. I had learnt hypernuclear physics from BM Udgankar and RH Dalitz's papers. After listening to SN Biswas's excellent lectures on integral equations I was impressed by the fact that integral equations can be easily solved if the kernel is separable. Using this, with SN Biswas's collaboration I could solve the two-channel problem of Lambda-Nucleon scattering. We applied it to Gell-Mann's global symmetry and proved that global symmetry that equated all the meson-baryon coupling constants does not work.

The next two papers [2,4] were in collaboration with Dalitz in Chicago. The first was on the lifetime of the light hypernuclei such as Lambda-H^3. The binding here is so weak that the life time is not expected to be very different from the lifetime of the free Lambda.

Experiments did not agree with this. This discrepancy exists even now and the problem is not yet solved!

The second paper on hypernuclear physics was on the binding of Lambda-Lambda hypernuclei. Here we had to do a three-body problem. We did a variational calculation with many parameters in the wave function. It was done using the new IBM computer in Chicago University. One punches the Fortran programme on cards and submits it. After several hours you are informed of the error in punching. You repeat the process. Finally I succeeded and the paper was written.

SU(3) and hadronic resonances :

At that time the dominant school of thought was the S matrix philosophy of GF Chew. Proving Mandelstam's double dispersion relations was considered the biggest challenge. Reinhard Oehme lectured to us on the many-sheeted S matrix.

AP Balachandran who had already obtained his PhD in Madras and joined as Dalitz's post-doc was frightening students like me by talking about the theory of many complex variables and "The Edge of the Wedge Theorem". He was very mathematically oriented.

Those days you either group or disperse. The former led to SU(3) group and the later led to Dispersion Relations. An interesting story about the proof of Dispersion Relations from Field Theory is the following:

Feynman: What is Dispersion Relation?

Wigner: What is Field Theory?

Chew: What is Proof?

I had mentioned to Dalitz that I would like to work on a problem nearer to the core of Particle Physics. Dalitz agreed and gave me a recent preprint from RJ Oakes and CN Yang that had arrived. They had criticized Gell-Mann's SU(3) on two counts:

1.The mass differences in the baryonic octet and the same in the mesonic octet being very large, the decimet baryons Delta (1238), Sigma (1370), cascade (1520) and $\Omega^-(1670)$ occur as poles on different Riemann sheets. So there is no way in which they can move smoothly to emerge as a single pole in the SU(3) limit.

2. Because of the large mass differences again, there is no way by which the perturbative Gell-Mann-Okubo mass formula can work.

Since I had learnt about the various Riemann sheets of the S matrix from Oehme's papers, I could answer the first objection: there is a retinue of poles residing in all the Riemann sheets. These were subsequently called "shadow poles". Because of the existence of shadow poles, one of the tenets of S Matrix theory which defines a particle as a pole

of the S matrix must be modified. The whole retinue of poles define the particle!

Any typical American physicist would have sent this to the Physical Review Letters immediately. Dalitz is more conservative and we sent a letter to Oakes and Yang and both of us left for Oxford! Meanwhile many others published this result. Later our delayed publications came out [3,5]. The second objection can be answered only by detailed calculations and that became my thesis[6]. I showed that if the momentum is small compared to the range of the interaction, perturbation theory is valid.

Dalitz, TC Wong amd myself wrote a paper [7] on the hadron Lambda (1405). We used a relativistic mutichannel version of Schrodinger equation with potential arising from exchange of rho and omega and could generate Lambda (1405).

When I returned to Bombay I began thinking about this problem. By that time quark model had come up. The question was: is Lambda (1405) a bound state of three quarks or is it a composite of a baryon and a meson? I discovered a way of answering this question.

I showed that the hadron Lambda (1405) cannot be a three-quark bound state, but it is a composite of a baryon and meson, the so-called "molecular hadron". The test was simply that if it were a quark composite, the K matrix for meson-baryon scattering must have a pole but such a pole did not exist for K bar-N, pi-Sigma scattering. I talked about this result in two conferences, HEP Symposium at Aligarh [10] and Matscience Symposium [13],but did not publish in any journal.

I learnt from my friend Sandip Pakvasa that my teacher Dalitz was not happy with me. Since earlier Dalitz, Wong and myself had worked on this hadron, perhaps he felt that he should be a coauthor in the K-pole paper. I wrote to him apologizing for what I did and explaining the circumstances in which this happened. Then I wrote a detailed paper in Physical Review [24] making due references to Dalitz's work and also thanking him. This paper contains a possible extension of the K pole text to many other hadrons too.

Much later after QCD came up, it was shown in the paper Phys Rev Let, 114, 132002 (2015) that QCD also supports the conclusion that Lambda (1405) is not a three-quark bound state.

In [8] I showed that in contrast to Lambda (1405) the decimet baryons cannot be meson-baryon composites, thus showing that the prevalent S-matrix bootstrap philosophy was wrong. With SS Vasan I showed the stability of the S matrix pole under various paramatrizations of the scattering amplitude.

Current Algebra, K decays etc :

During 69-71, current algebra became the main focus. I wrote a few papers connected to Schwinger terms in collaboration with V Gupta [15,16,20]. This led to the discovery of a fixed pole in virtual Compton amplitude [21]. This paper has an interesting history. Rajaraman and Sudendhu Roy Chowdhuri had sent out a preprint pointing out a discrepancy between a theoretical sum rule and data on deep inelastic electron-nucleon scattering data. I could immediately see that they had ignored a possible fixed pole which is indicated by our earlier work on Schwinger term in Current Algebra. I pointed this out to Rajaraman who was visiting TIFR. On his return to Delhi he corrected the preprint and published it with SR Choudhury. So, actually the paper [21] is redundant!

I reviewed [11] an important paper of Abers, Dicus and Norton who derived the radiative correcton to beta decay using Current Algebra.

The paper [17] was written with KVL Sarma and it addressed the question of electron-muon universality in K decays. This is a recurrent topic and right now this family universality is an important topic in B decays. Papers [18],[19] and [23] written in collaboration with a student SC Chhajlani and LK Pandit applied Current Algebra to K decays.

With PP Divakaran and V Gupta I studied the question whether the electromagnetic current could have an $I = 2$ component [12]. The paper [27] with PP Divakaran connected the form of the deep inelastic structure function with the asymototic behavior of the elastic form factor.

Post-Standard Model

Gauge Theory :

I became aware of Yang-Mills (YM) theory by reading J J Sakurai's paper in Annals of Physics in 1959. That was the first paper in which YM was used in particle physics. Sakurai constructed a gauge theory of strong interactions. I continued to be interested in YM theory from that time. Veltman's lecture at Varenna where he talked about the conserved weak current impressed me very much and I felt that weak interaction must be described by a YM theory. So, when Weinberg's paper on the SU(2)xU(1) electroweak theory came out in 1967 I had no doubt that was the correct theory. I read the papers of Goldstone, Higgs and Kibble.

In the subsequent two or three years, I lectured on these at various places including TIFR. In particular, in June 1971, I gave a series of lectures on the gauge theory of weak interactions including Yang-Mills theory, Faddeev-Popov ghosts, Higgs mechanism,

electroweak theory, GIM mechanism etc. It came out as a SINP report [25]. This was the first connected account of what became known as the Standard Model, anywhere in the world! It even contained my conjecture that the massless YM gauge quantum cannot exist as a particle because of the incurable infrared divergences (an early suggestion of what became known later as infrared slavery and colour confinement). These lectures were given even before t'Hooft's proof of renormalizability appeared!

Nevertheless I failed to make any substantial contribution in gauge theory. I will not go over the reasons here.

Then came the discovery of asymtotic freedom of YM theory by Gross, Wilczek and Politzer and the construction of SU(3) colour gauge theory by Gell-mann, Fritzche and Leutwyler to describe strong interactions.

Renormalizabily of YM with SSB and Asymptotic Freedom are the two most important discoveries in Quantum Fild Theory after the discovery of renormalizability of Quantum Electrodynamics in 1947-49. I missed the boat in both, although I was well-placed with potential to contribute. I had already studied path integrals which t'Hooft used in his proof and was already giving lectures on Wilson's Renormalization Group and Callan-Symanzig equations which are the ingredients in the discovery of asymtotic freedom by Politzer, Gross and Wilczek.

Although I missed the stage, I was sitting in the front row. I could catch their significance as soon as the discoveries came tumbling one after another! The years 1971-73 were truly exiting years. It was the watershed in the development of High Energy Physics.

In [26], I showed that divergences in the higher-order corrections calculated in the SU(2)xU(1) theory cancel.

In the First Symposium on HEP at Bombay in 1972, I reviewed the electroweak theory [29]. This was the first review of the electroweak theory in the country.

Actually, until t'Hooft's proof, as far as I know, nobody except Joe Schechter in Syracuse University who added a U(1) to cancel the strangeness-changing neutral current and myself had taken Weinberg's theory seriously. Even after t'Hooft, only a few theorists took it seriously. Situation changed dramatically after the discovery of the weak neutral current interaction in the CERN experiment by Perkins and others in 1973.

In 1969, TIFR's theoretical physics summer school was held at Nainital. Some memorable events took place there. Both Geoffrey Chew and Francis Low lectured. Chew lectured on S Matrix Theory. I asked him a question: Since S Matrix theory addressed only strong interactions, what happens to weak and electromagnetic interactions? Chew

gazed at the distant Himalayan peaks visible through the window for a few minutes and simply continued his lecture.

Low lectured on the divergence problem of the Fermi theory of weak interaction and described all the methods proposed to deal with the problem. This was two years after Weinberg's paper. I asked Low at the end of his lectures why was he ignoring the Yang-Mills theory of weak interactions. He merely stared at me and refused to answer my question. He described seven or eight unnatural ways of solving the weak interaction problem but left out the one way that turned out to be the right way. To this day I have not understood how such a thing is possible, Low being a very experienced physicist. Somebody said it was because Low did not like Weinberg! Tapas Das and myself took notes of Low's lectures and brought it out as a TIFR yellow report.

The evolution of the name starting from Gauge Theory is interesting. As soon as t'Hooft showed the renormalizability of electroweak theory I calculated the radiative correction to muon decay and sent it to Physical Review for publication[26]. I had put the title as "Radiative correction to the muon decay in gauge theory". Physical Review changed it to "Weinberg's gauge theory". In 1972 the HEP Conference was held at Chicago that I attended. That is where gauge theory was presented as a Rapporteur's talk for the first time. BW Lee gave the talk. He called the theory as "Salam-Weinberg gauge theory". Salam and Gell-Mann were sitting in the first row and I happended to be sitting in the second row just behind Salam and Gell-Mann. As soon as Lee mentioned "Salam-Weinberg gauge theory", Gell-Mann gave a nudge to Salam with his elbow. Later when the Nobel Prize was given, Glashow's name was added and the theory became Glashow-Salam-Gell-Mann theory. This is certainly justified since Glashow was the first to discover that SU(2)xU(1) was the correct gauge group for electroweak theory and also he was one of the inventors of the Glashow-Iliopoulos-Maiani (GIM) mechanism to remove the strangeness changing neutral current.

However I prefer to call it the SU(2) x U(1) Electroweak Theory.

Neutral Current :

Weak neutral current (NC) interaction is almost as strong as the usual charged current (CC) weak interaction but lay undiscovered all those years. It could have been discovered many years earlier if only the experimenters did not listen to some theorists who said NC cannot exist. The theorists thought that NC would lead to strangeness changing NC decays which were not seen, but they forgot that there could be strangeness nonchanging NC. So the experimenters ignored some data which were actually due to NC. But the

clinching experimental proof was possible only after the huge Gargamelle bubble chamber was constructed at CERN. Because of its size they could clearly distinguish a pion from muon and this was crucial for the discovery of NC through the absence of muon in neutrino collision.

As soon as the discovery of NC was announced, KVL Sarma and myself produced the first model-independant analysis of deep inelastic data [30,32,33]. JJ Sakurai called our equations "Master Equations". His analysis of elastic scattering using the master equations coupled with LM Sehgal's of single pion production led to the complete determination of NC coupling constants. Later with Sandip Pakvasa, I generalized the analysis to include S,A and T neutral current interactions. With KVL Sarma I wrote two more papers on this topic [44,52]. With SH Patil I calculated the contribution of neutral current to the decay $K_L \to \mu^+ + \mu^-$ [28].

Integrally charged quarks :

Our work on Integrally Charged Quarks (ICQ) has a curious history. While working on the neutral current paper [35] with Pakvasa, I noticed that if there are charged spin one partons, deep inelastic structure functions will not scale. Probir Roy and myself pointed this out for the neutral current [37]. We noticed that scaling will be restored in a unified gauge model. This is how we arrived at the Han-Nambu model which we gauged. The results were remarkable:

1. Although the Han-Nambu quarks are integrally charged, as observed through high q^2 probes, they behave like the Gell-Mann-Zweig fractionally charged quarks (FCQ).

2. Gluons acquire electrical charge and have weak interactions also.

Papers [40,42] are on this work. I derived these results in a somewhat more general way in [43].

Soon we saw a preprint by JC Pati and Abdus Salam who also had the same model with ICQ. But they did not notice the second result, namely the gluons have electrical charge. We pointed this out to them in a letter and immediately, Salam sent a cable "We were wrong and you are right." They also corrected the published version of their preprint.

After I joined Madras University I worked with my collaborators SD Rindani, T Jayaraman and S Lakshmibala and confronted the ICQ model with experiments on deep inelastic scattering and electron-positron annihilation and also analyzed other consequences of the model [54,61,63,64,65,66,70,71,78,79,82,83,86,87,88,98]. In some of these papers there were other collaborators: HS Mani, R Godbole, JC Pati, X.-G He, S Pakvasa, and NG Deshpande. To this day, the ICQ model has not been disproved.

Some of the other works on the broken colour model are [70],[98].

In an important paper [81] with T Jayaraman and SD Rindani it was shown that the time- honoured Equivalent Photon Approximation does not work for massive spin-1 charged particles unless modified suitably. This was inspired by our work on ICQ model.

Some time ago, I noticed that the model with broken colour solves the problem of strong CP violation from which the standard QCD suffers. I have not yet published this result.

How I proved three Nobel Laureates wrong! :

1. Our discovery of shadow poles in disproving CN Yang's objection to SU(3) has been already described.

2. The discovery of CP violation in 1964 by Cronin and Fitch created quite a lot of excitement. V Gupta returned to TIFR after a stay at Caltech and he showed me a Phys Rev Lett paper in which he had proposed what looked like a very elegant model of CP violation. He had discussed this with Gell-Mann. I spotted a big error that Gell-Mann did not notice! This model violated CPT theorem and hence is untenable!This paper [9] is the shotest paper I ever published.

3. While working on ICQ model, we showed Salam was wrong. This is described above.

I have to balance the above by the following.

My failed attempts :

1.This was soon after I joined TIFR in 1958. In the primordial nucleo synthesis there was a gap. In the successive cooking of nuclei starting from proton by abrorption of a neutron, there seemed to be a gap at A = 5. Because He^5 is not bound. When I learnt that the hypernucleus Lambda-He^5 is bound, I thought that is the solution. I discussed it with Udgaonkar, but it did not work.

2.After CP violation was discovered from K decays into two pions in 1964, I thought the ugly CP violation can be avoided by recognizing that since pions are quark-antiquark bound states, Bose statistics for pions is only approximately valid and without Bose statistics, CP violation cannot be inferred. This idea too did not work.

3.During 1964-64, with Arvind Kumar who joined me as a student, I undertook a massive calculation aiming to construct a complete theory of hypernuclei. Infact Arvind Kumar managed to do an enormous amount of calculation. It did not lead anywhere.

4.I tried to generate the nucleon-pion coupling using the quarks of which N and pi were made. This also did not lead anywhere.

5.For quite a long time,I imagined quarks to be leptons. That would have been the natural explanation for quarks and leptons satisfying the same current algebra. I tried to construct a mechanism by which the weakly interacting leptons could sometimes exhibit strong interactions, but I failed.

6. During 1967-70, I tried to construct strong interactions from weak interactions. by using the divergences of Fermi's weak interaction theory. TD Lee had shown how the quadratic divergences could be turned to strong interactions. Gell-Mann, Goldberger, Kroll and Karplus wrote a nice paper showing how the quadratic divergences in the diagonal parity and strangeness conserving sector could be identified as the strong interactions. My aim was to redo these calculations using the YM theory of weak interactions of Weinberg's 1967 paper. But alas! t'Hooft proved the renormalizability of Weinberg's theory. No divergences were left to generate strong interactions!

Psi particle :

In 1974 I was invited by my friend Sandip Pakvasa to visit the University of Hawaii, Honolulu. Sandip and myself worked on the paper [35]. Since I had gone with my family, I wanted to show them Hawaii. But in October of that year all hell broke loose! A very narrow peak at 3.1 GeV was seen in electron-positron collisions. San Fu Tuan was constantly at the phone pumping out information on the new discovery from Stanford and other Centres. We wrote up a dozen explanations[34]. Fortunately it included the correct explanation: it was a bound state of the new charmed quark and a charmed antiquark. Papers [36,39,41] on the charmed particles were written in collaboration with J Pasupathy and KVL Sarma.

Madras University :

In 1976 I shifted to University of Madras. I was very much worried since this happened when I was at the peak of my career and feared that my academic performance will be afftected. Fortunately this did not happen, mainly because of a brilliant physicist V Srinivasan. Using functional methods, Srinivasan and myself could show the equivalence of many field theories. In particu;ar we could show the equivalence of Parisi's model of quark confinement with QCD! [46,47,48,49,80] are the papers written in collaboration with Srinivasan; in the last paper MS Sriram also was a coauthor.

Soon SD Rindani joined as a faculty member and Sriram and JK Bajaj joined as

Research Associates under my UGC project "Gauge Theory". Under the enlightened leadership of the Vice Chancellor Malcolm Adiseshaiah, MSc teaching started. Two good MSc students T Jayaraman and S Lakshmibala joined me for PhD. So we had built up an active Theory group in the University.

Activities in IMSc Phase

Quantum Statistics :

After I rejoined Institute of Mathematical Sciences after one year at TIFR, AK Mishra joined IMSc. He is very good at long algebraic calculations. One day he came to my office and showed me a new algebra of creation and destruction operators. He constructed this while studying Hubbard model where the Coulomb interaction between electrons at the same site is so large that only one electron is allowed at one site. This was the starting point of our long and fruitful collaboration. We constructed a Generalized Fock Space which allowed us to discover many new forms of quantum statistics [115]. These were Orthostatistics, Null Statistics, Hubbard Statistics and many others [102,106,107,108, 108,116,111,112,113,118,120,123]. Some related work with AK Mishra, A Khare and RP Malik was published in [107,108,127].

Neutrinos :

Neutrino Physics came to centre stage after the discovery of neutrino oscillations. Most people worked on the toy model of oscillations with two neutrinos. The Madras group was one of the earliest to work with the full three-neutrino oscillations. In [121] and [122] I worked on solar and atmospheric neutrino oscillations with MVN Murthy, S Uma Sankar and Mohan Narayan. We were the first to give the correct interpreation of the null result that came from the CHOOSE reactor experiment [132]. We could give an upper bound on the reactor mixing angle θ_{12}. This upper bound of 11 degrees was the only information on this mixing angle until Daya Bay experiment determined it to be about 9 degrees, not farway from our upper bound.

Since we had an analytical way of doing neutrino propagation in matter, Rahul Sinha, Mohan Narayan and myself could do many calculations more easily. We could calculate in detail the time-of-night variation of solar neutrinos during their passage through the Earth [125]. In collaboration with C Burgess we could calculate the Eclipse Effect in which neutrinos get regenerated during their passage through the Moon [124, 126]. So, as observed through a neutrino telescope, the Sun appears brighter during the eclipse!

I worked on neutrinos from Supernovae in collboration with MVN Murthy, D Indumathi and G Dutta.[135,140,143]

Most of this work was reviewed in [130].

Using RG evolution we showed how the neutrino mixing angles which are small at high scales evolve to become large at small scales and match the experimental values [151,156,158,164]. My collaborators were RN Mohapatra, and MK Parida and later SK Agarwalla. In collaboration with G Abbas, S Gupta, R Srivastava, MZ Abyaneh and M Patra these calculations were pursued with updated input and in one paper,replacing Majorana with Dirac neutrions [181,182,185].

In all the above RG work, the neutrino mixing angles were taken to be equal to the quark mixing angles at high scale under the assumption of lepton-quark unification. Later I realized that this unification hypothesis was unneccessary. What was needed was the Wofenstein structure for the mixing matrix. This important result is in paper [190].

In collaboration with PP Divakaran a new mechanism for the tiny neutrino masses was proposed [134]. This will make the Higgs boson a composite object.

In the context of the alleged superluminal velocity of neutrinos in the CERN-GranSasso experiment, we (D Indumathi, Romesh Kaul, MVN Murthy and myself) calculated the group velocity of the three neutrino flavour complex and showed it is not superluminal. Later the experimenters withdrew their result on superluminal velocity.

The scale of the dark energy and the neutrino mass are comparable. If this is not an accidental coincidence, they must be physically related. Such a possibily is realized if the neutrino condensate is the origin of dark energy: paper[168] with JR Bhatt, Bipin Desai, Ernest Ma and Utpal Sarkar.

Model Building :

In collaboration with the model-builder 'par excellance' Ernest Ma of University of California, Riverside I did much work on Model building for neutrino masses and mixing and also for other things [141,142,147,148,149, 152,159,165,188]. Paper[146] on A_4 turned out to be very popular, as evidenced by its large citation index.

Papers [155,157,160] on SO(10) and seesaw were written in collaboration with Bipin Desai, Utpal Sarkar, K Bhattacharya and CR Das.

String Theory :

I was aware of String Theory almost from its birth. When I was perusing the preprint library in KEK, Japan in 1980 I saw the paper of Scherk and Schwartz who liberated String

Theory from its hadronic context by changing the string tension from 1 GeV to 10^{19} GeV. That was the birth of String Theory. Then in 1984 I was escorting Tullio Regge from Bangalore to Madras and he told me the exciting discovery made by Green and Schwartz that all the anomalies cancel in the SO(32) and $E_8 \times E_8$ Superstring theories.

From then on I learnt whatever was known in String Theory and gave lectures on it in various Conferences, Workshops and the SERC School [84,92,94]. But because of the heavy work involved in the building up of IMSc (1984-88) and the turmoil in the Institute in 1989, I could not work in String Theory. But I kept up my interest in it because I believe that is the Theory for Future incorporating Standard Model and Quantum Gravity.

In 1987, I gave a series of lectures on String Theory at University of Hawaii,Honolulu. At that time, a strong criticism of string theory by P Ginsparg and S Glashow appeared in Physics Today. I answered that criticism in my lecture. San Fu Tuan persuaded me to write that up and send it to the journal. I agreed to publish it with him as a coauthor. In this I speculated that not only one-dimensional strings but consistent theories of multi-dimensional objects also exist. Later, as is well known, Polchinski discovered the mutidimensional branes as solitons in string theory.

The main problem with String Theory is the lack of experimental support. That requires construction of accelerarors going upto Plank energy 10^{19} GeV. Many regard that as impossible. This is a crisis in Physics. But human ingenuity knows no bounds and this energy barrier will be crossed. New principles of acceleration will be discovered. I have been emphasizing this for the last 40 years. Laser Plasma Acceleration (LPA) is one such and it has been pursued for some time all over the world. I have discussed the importance of starting LPA with experts on lasers at TIFR, Centre for Advanced Technology, Institute for Plasma Research and BARC. All of them met at the International Centre for Theoretical Sciences and they are chalking out a plan of action.

Kolar events :

One morning, my wife who was looking at the Times of India, exclaimed "Look, your friend KVL Sarma's name is in the front page!". I looked and found she had missed my name. The news item in the front page said G Rajasekaran and KVL Sarma have discovered a new particle. The Kolar experiments discovered some events that could not be explained. KVL Sarma and myself interpreted those events as due to a new paricle. I also described this in an article in Physics News. TOI looked at only this popular science article and wrote the story. I was flabbergasrted. There was no mention of the experimenters (that included MGK Menon). I contacted TOI and asked them to withdraw

the story or atleast correct it. They refused and said I can send a letter to the editor.

TOI could have verifed the authenticity of their story by phoning TIFR. They did't. This is the level of science reporting!

Recently at IMSc, MVN Murthy and myself have interpreted the 40-year old Kolar events as due to decaying Dark Matter particles.

Miscellaneous topics :

A large-N gauge theory of loops was constructed by B Sakita, but he did it only for pure YM theory. Hendrik Bohr and myself extended it to the matter sector[69], (Hendrik was rhe grandson of Niels Bohr's brother Harald Bohr).

A unified treatment of Bohm-Aharanov effect for electromagnetic field and Collela-Overhauser effect for gravitational field in five-dimensional Kaluza-Klein theory was given in [193]. Later it was extended to include Berry phase [119].These works were in collaboration with R Parthasarathy and R Vasudevan.

The consequences of noncommutative Standard Model were worked out for some physical processes: papers [166,169] with PK Das, NG Deshpande, SK Garg and T Shreecharan.

HEP is moving through greater depths down to 10^{-33} cm in attempting to encompass Quantum Gravity. In this venture, will Quantum Mechanics remain valid for ever? In what way can it be modified? I discussed this question 30 years ago [192].

Reviews :

I have spent a considerable amount of time and energy in giving review talks and writing review articles. Some of these are [51] which are Panchgani lectures on Gauge Theory, [91] which is a course of lectures on the construction of the Standard Model,[92,94] on String Theory, [100] on electroweak symmetry, and general reviews on the state of HEP [90,104,114,128,129,175]. Article [162] traces the panoramic history of HEP while [163] gives the history of the establishment of scientific institutions in South India during the British period.

Some topical reviews are in [171,172,174,176,177 and 187]

Is God subtle? :

Einstein said: "Subtle is the Lord; malicious He is not." Let us analyze whether the Lord is really subtle.

In the 60's and early 70's, there were many subtle and sophisticated ideas on how to solve the problem of hadrons -S Matrix theory, currents as coordinates, infinite component wave equations and many more. I have already mentioned some of these above, as my failed attempts.

The simplest interpretation of the Sakata-Gell-Mann-Neeman SU(3) in terms of a triplet of quarks as the building blocks of all hadrons turned out to be right although most physicists took a long time to realize it.

After the success of the YM paradigm in the electroweak sector a mindless repetition of the same in the strong sector appeared naive, but that turned out to be the correct solution for the strong interaction. That is QCD.

After the neutral current was discovered, I had hoped that Nature would spring a surprise. I had thought a more subtle manifestation of SU(2) X U(1) symmetry without gauge bosons would be the truth. But W and Z were discovered precisely at the masses prdicted by theory.

Finally I had hoped that Higgs boson would not be discovered since the actual mechanism of spontaneous symmetry breaking could be more subtle than what Higgs and Kibble had imagined. Again I was wrong.

Hence the question: Is God subtle?

Standard Model is not the end of the story. Maybe the subtle and sophisticated ideas will have their day when we go deeper in our INWARD BOUND journey.

Chennai Mathematical Institute (CMI) :

Seshadri founded CMI with Mathematics and Theoretical Computer Science. Even before IISERs came, Seshadri admitted into CMI talented students after school so that they can pursue their studies in an atmosphere of research. He wanted CMI to grow into a full-fledged University and as a first step wanted to have Physics. He asked me to help in Physics Faculty recruitment and teaching. I have been doing that. We now have a Theoretical Physics Group of outstanding young faculty members.

Some of the other institutions in whose development I played a role as a member of their Governing Council or other bodies are Harishchandra Research Institute, Institute of Physics, Saha Institute of Nuclear Physics, Inter-University Centre for Astronomy and Astrophysics, Indian Institute of Astrophysics, SN Bose Centre for Basic Sciences and IISER, Thiruvananthapuram.

Teaching :

Apart from teaching full courses at CMI, I have been involved in considerable teaching in other Centres too. Academies-organized Refresher Courses in many Colleges in Tamil Nadu, Kerala and Karnataka took up a lot of my time and energy. For many of them I was the Director. Sunday Classes (venue: Dept of Nuclear Physics of the University) were started by Satyanarayana of Pondycherry University with the help of Joseph Prabagar of Loyola College. I joined the team and taught. I was involved in the running and teaching in the DST-organized SERC Schools in Theoretical High Energy Physics for more than ten years and I initiated the Physics Teaching for Talented Students which is being carried on successfully by M Sivakumar, MV Satyanarayana and Raghavan Rangarajan. Courses in High Energy Physics were given by me at IISER-Thiruvananthapurm, IISER-Mohally, Banares Hindu University Madurai Kamaraj University and many other institutions.

Popular Science in Tamil :

I strongly believe that Popular Science will succeed only if it is done in the mothertongue of the people. My ambition to write Science in Tamil fructified through the kindness of my friend Dr Jeyapragasam who was the Editor of a Tamil monthly published from Madurai. I wrote every month and brought out two volumes containing my articles.

Raju Raghavan :

Raju Raghavan was a great experimental physicist. Although I knew him earlier since he was a second batch trainee, we became friends only after I came to Madras. He used to visit me whenever he came from USA and we discussed neutrinos. He had many original ideas on neutrino detection, including Mossbauer resonance absorption and emission of neutrinos. If one succeeds in this, neutrino experiments can be done on a table-top!

Later, after INO was conceived he was its enthusiastic promotor. He had conceived a detector of solar low energy neutrinos, called LENS (Low Energy Neutrino Spectrometer) which can revolutionize solar neutrinos physics. He wanted to do the experiment in India. I took him to meet the secretaries of DAE and DST and they agreed to support him.

But Raghavan passed away suddenly in 2011. I was shocked and took a long time to recover. Actually at that moment when I heard the news, I was arranging a major meeting of Raghavan with scientists and science administrators. His death is a serious loss to Indian Science. India must take up the LENS Project.

India-based Neutrino Observatory (INO) :

India was a pioneer in neutrino experiments. The very first observation of cosmic ray

produced neutrinos called atmospheric neutrinos was made in India, in the Kolar Gold Field (KGF) mines. That was in 1965. But the mines were closed in the 90's. Since there was not much gold, the Bharath Gold Mines company decided to close it. We should not have let that happen. Science is more than gold! It is these atmospheric neutrinos whose further study by the Japanese physicists yielded two Nobel Prizes, in 1998 and 2002. We clearly missed the boat.

Can we recover this lost initiative? We can and we must. The INO was conceived with this aim in view.

It was conceived in IMSc in the year 2001, but it has not still seen the light. It was approved by all the Central Government bodies and the Government granted Rs 1600 crores for the project. This involves the construction of a 50,000 ton magnetised iron calorimeter detector for atmospheric neutrino studies. This will be installed inside a mountain in Theni District. The nerve-centre of INO will be in the outskirts of Madurai City and will house R and D of particle detectors with training facilities for students. This has been named Inter-Institutional Centre for High Energy Physics (IICHEP).

Apart from the study of atmospheric neutrino oscillations, INO lab will house experiments searching for Neutrinoless Double Beta Decay (NDBD) and Dark Matter (DM). CVK Baba and myself played some role in initiating the NDBD activity. As a consequence two or three groups involving Vandana Nanal, RG Pillay, PK Raina and PK Rath are involved in feasibility studies for the NDBD project. I tried to initiate work on Dark Matter Search through Rupak Mahapatra of Texas A and M and physicists at SINP. This could have been a major project but it did not succeed. Instead a minor Dark Matter project at a shallow depth in the Jaduguda mines has been started.

Along with others I have lectured on INO to students in colleges and schools and villagers as a part of of the INO's outreach programme. This is continuing.

Some "wise men" of Tamil Nadu blocked INO citing non-existent environmental and other imaginary dangers. This obscurantist propaganda must be fought and INO must succeed. Truth has to triumph.

Appendix to Part II: List of Publications

1. $\wedge$ - binding in hypernuclei by nonlocal interaction, (with S.N. Biswas), Phys. Rev. **122**, 712 (1961).

2. The spins and lifetimes of the light hypernuclei, (with R.H. Dalitz), Phys. Letters 1, 58 (1962).

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5. Scattering amplitudes on unphysical sheets and resonance poles, Nuovo Cimento **31**, 697 (1964).

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8. Decimet Baryons as "Elementary Particles", Phys. Rev. **159**, 1488 (1967).

9. Current Commutator and CPT, Phys. Rev. **160**, 1427 (1967).

10. $Y_o^\star$ (1405) as a possible exception to the quark-picture of Hadrons - *Proc. of the Tenth Symposium on Cosmic Rays, Elementary Particles and Astrophysics*, Aligarh, 1967, P.521.

11. Radiative Corrections to β decay - *Proc. of the Tenth Symposium on Cosmic Rays, Elementary Particles and Astrophysics*, Aligarh, 1967, P.507.

12. Does the electromagnetic current have an I = 2 component? (with P.P. Divakaran and V. Gupta), Phys. Rev. 166, 1792 (1968).

13. Can $Y_o^\star$ (1405) be a bound state of three quarks? Symposia on Theoretical Physics and Mathematics (Plenum Press), Vol. $\mathbf{9}$, 531 (1969).

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15. Restrictions on Schwinger Terms due to Lorentz Covariance, (with V. Gupta), Nucl. Phys. $\mathbf{B\ 10}$, 11 (1969).

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