RAJAJI- AN INWARD BOUND JOURNEY

Trends in Astro-particle and Particle Physics

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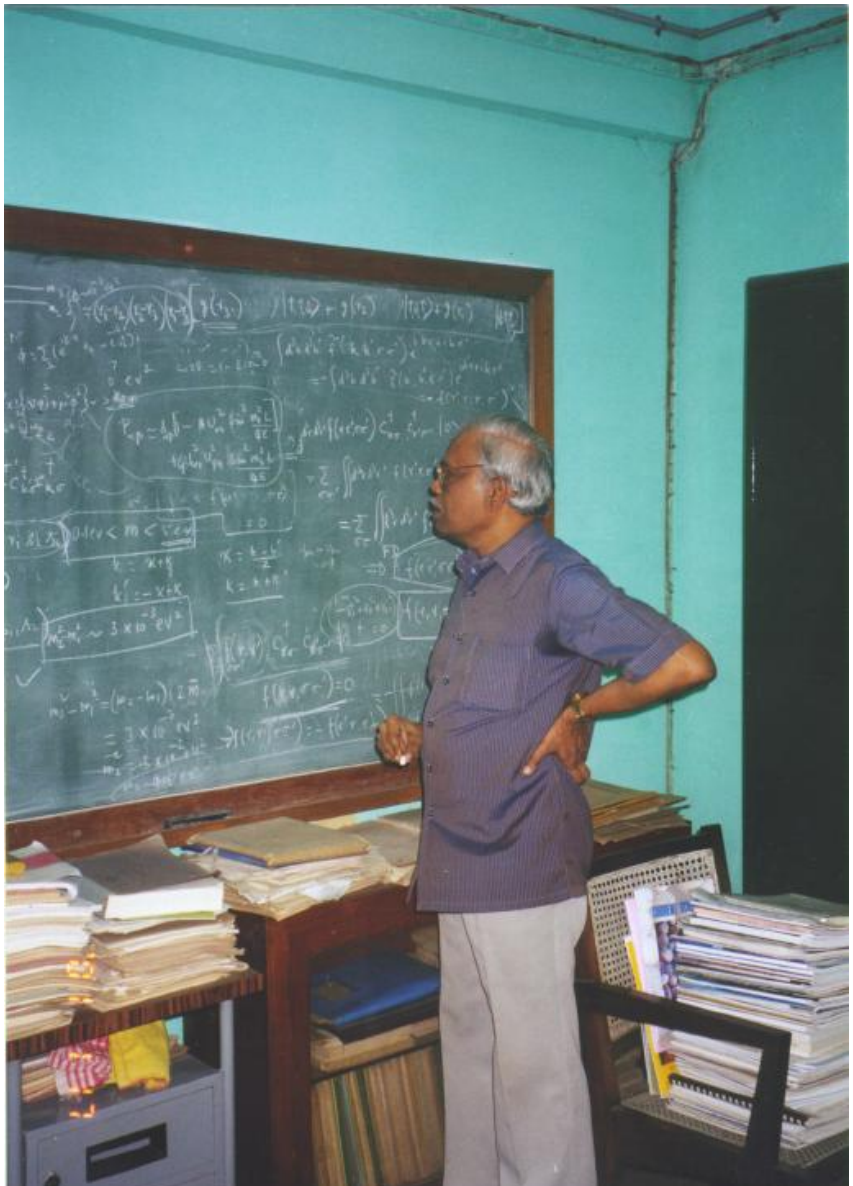
Thanks to: PP Divakaran, Vivek Datar, HS Mani, Uma Harano, CS Sundar

Outline

- Growing up
- Scientific contributions
- Rebuilding IMSc
- Back to research-INO
- Teaching/Outreach



Early Years

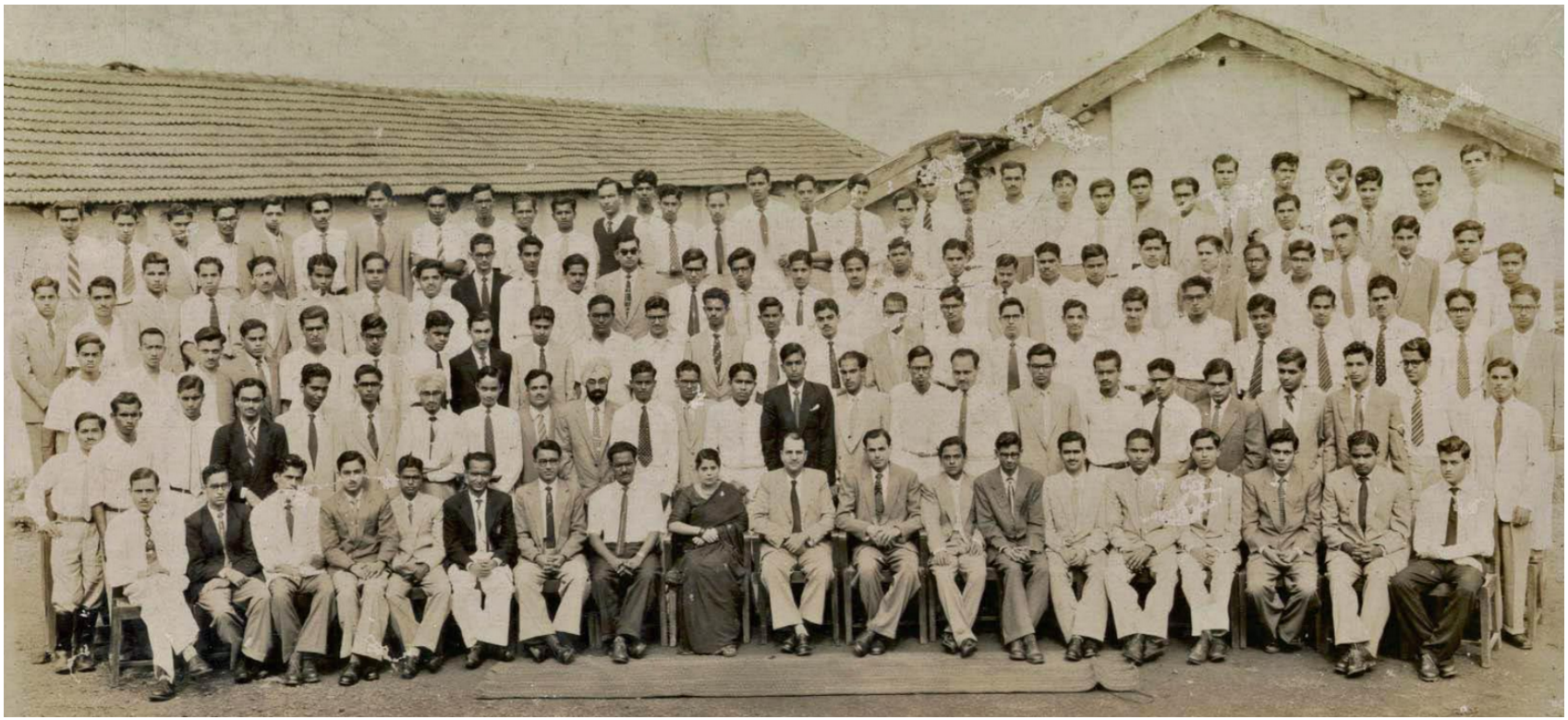
Rajaji was born in 1936 in the the town of Kamudi in Ramanad district of Madras Presidency; eldest of 5 brothers and 4 sisters. Father owned a small shop selling vessels.

Education

- Early schooling in Kamudi.
- Intermediate from American College (1952-54).
- B.Sc(Hons)Physics from Madras Christian College (1954-57).
- Atomic Energy Establishment, later BARC, Training School. (1957-58). First among 150 trainees in the first batch.
- Joined TIFR- (1958-61)-Started working on Hyper-Nuclear Physics, and then digging deep into Quantum Field Theory with other colleagues.

Rajaji had started supporting his family when he was in TIFR, ensured that the support continued even when he went to Chicago for his Ph.D.

Early Years- Training School 1957-58



First batch of training school 1958- among his batch mates were CVK Baba, KVL Sarma, SS Jha, NS Satya Murthy, MP Parameswaran, ... many illustrious names who not only enriched AEE/TIFR but also many other areas and institutions.

TIFR-1958-61

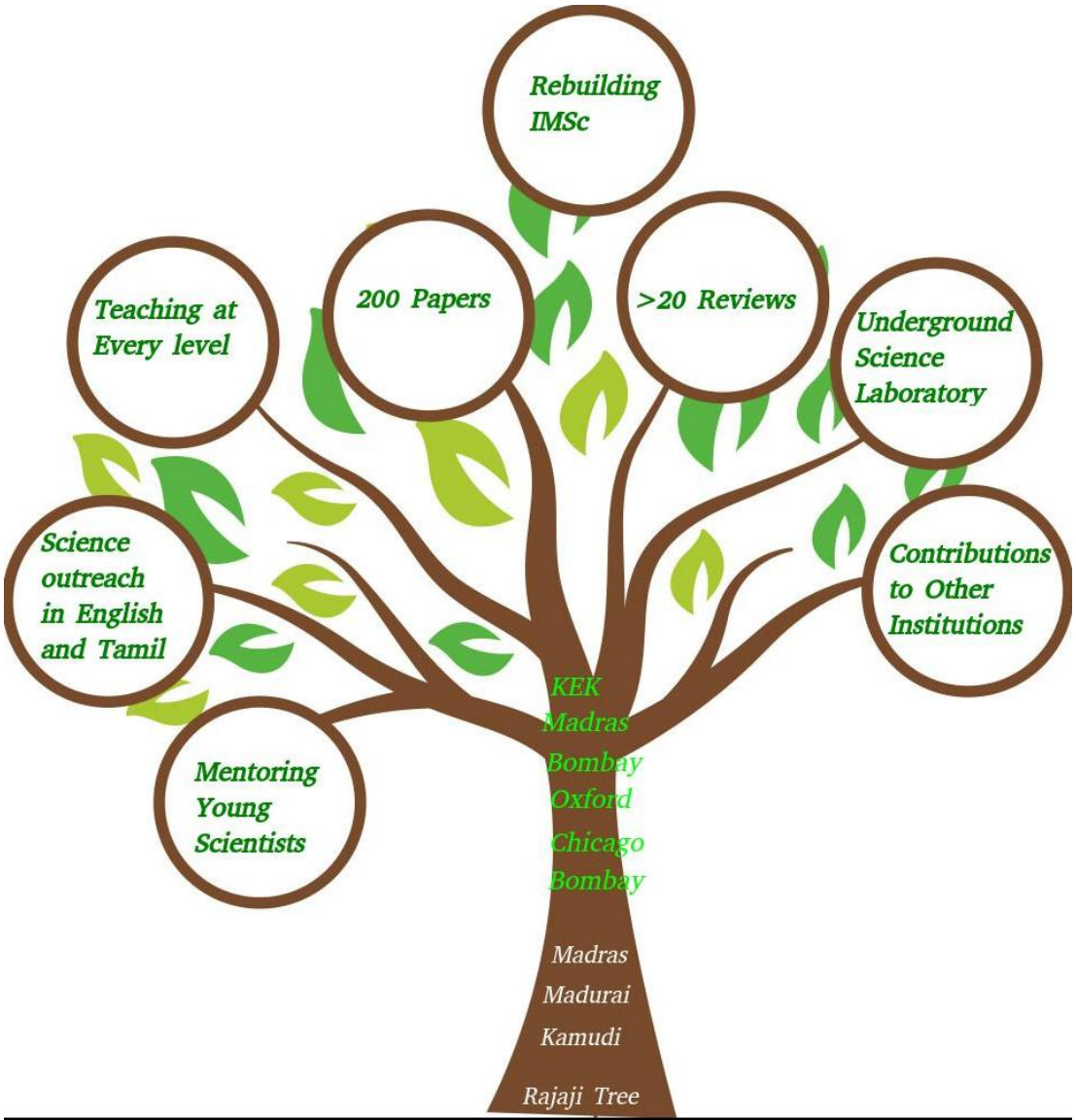
... Bangalore Summer School and where the Eightfold way was first announced!

As was the norm in TIFR those days, Rajaji was packed off to Chicago for doing Ph.D much against his will initially. Richard Dalitz, whom he had met in the TIFR summer school in Bangalore in 1961, took the initiative to bring Rajaji to Chicago; Topped the dreaded "Chicago Basic" exam. This increased the stock of fellow Indian students.

In Chicago A K Ramanujan was working on Sangam literature. Rajaji's knowledge of Tamil language and literature was a great help to Ramanujan!

Scientific Contributions

Rajaji's scientific endeavours lasted more than 60-years. This is a small selection, biased of course, of his contributions.

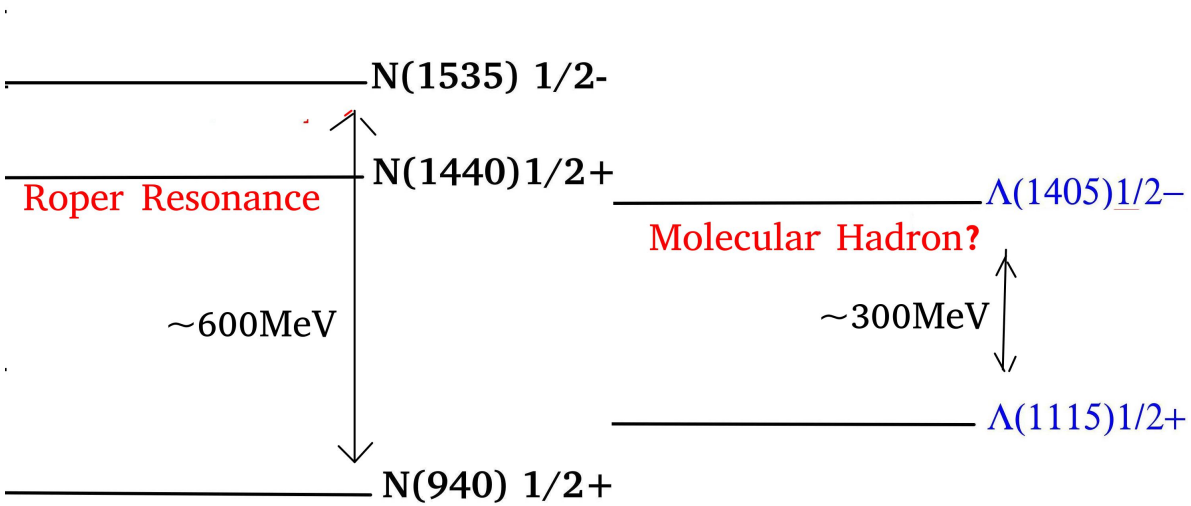


Chicago and Oxford

- Work on "Shadow Poles" was the core of his thesis. The decuplet baryons appear as poles in the S-matrix on different Riemann sheets which do not collapse into a single pole in the SU(3) symmetry limit. This was the basis of objection to Quark-model by Oaks/Yang as also the huge mass differences among the decuplet baryons.
- Rajaji solved the problem by showing that "there is a retinue of poles in different Riemann sheets corresponding to a single baryon". This was the discovery of what are now called "Shadow Poles".
- This discovery of "shadow poles" not only removed a serious obstacle but also led to a reformulation of a basic tenet of the S matrix theory.

Rajaji completed his thesis in just under 3-years, spending a year in Oxford, returned to TIFR in 1964. His defense was conducted by post by a committee headed by Telegdi !

Baryon Molecule!



Nucleon & Lambda Excitations

The Baryon resonance $\Lambda(1405)$ is an open problem in QCD- comes too low in excitation energy. Rajaji and coworkers suggested that $\Lambda(1405)$ can not be a three quark baryon, but should be a molecular hadron, a bound state of $\bar{K}N$. This was an audacious suggestion in the 60's.

Baryon Molecule: Growing Evidence from LQCD

physicsworld

Mysterious baryon resonance is a subatomic molecule, say physicists

physicsworld.com, 07 Apr 2015

Strange quark does not contribute to magnetic moment of lambda 1405

ScienceNews

Exotic particle turns out to be quark molecule

Science News, 03 Apr 2015

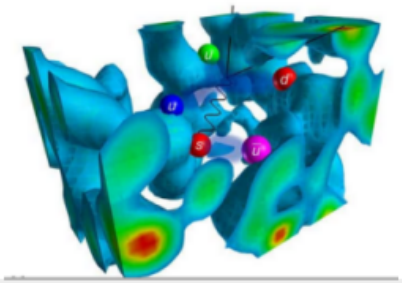
Subatomic particles made of quarks can bind together to form molecules, according to a computer simulation of a long-studied...

PHYS.ORG

Supercomputer study shows Lambda baryo quark molecule

Phys.org, 06 Apr 2015

(Phys.org)—A team of researchers with the University of Ad Australian National University has found that the...



"In the 1960s the Australian physicist Richard Dalitz and colleagues suggested that that $\Lambda(1405)$ could comprise an anti-kaon meson bound to a nucleon. ...However, over the past two decades theoretical support for molecular $\Lambda(1405)$ has grown, with calculations done by several groups of physicists backing up the idea." (Physics News) (Derek Leinweber et al).

Towards Standard Model- Gauge theories

- Rajaji was a very early proponent of gauge theory. His lectures delivered at the Saha Institute in 1971, and elsewhere, was the first coherent account of the Yang-Mills Fields and Salam-Weinberg electro-Weak Theory (TIFR/TH/72-9-Unpublished) well before it became paradigm of HEP.
- The Lecture notes even contained his conjecture that mass-less YM gauge quantum can not exist freely because of infrared divergence (or infrared slavery- a hint of colour confinement before the advent of QCD.)
- *"I got hold of his lectures on Yang-Mills theory given at Saha Inst. (around 1970-71) which became my bible; I still have my marked up and dog-eared copy. This contains prescient remarks about confinement and other ideas."* Sandip Pakvasa. Similar sentiments expressed by Lalit Sehgal too.
- Perhaps Rajaji's best work is the 1-loop finite renormalisation of mu-decay; following 't Hooft's general theory. It was the first finite non-tree level computation in the standard model, though not the first to be published.

Towards Standard Model

The E-W gauge theory was not taken seriously until the discovery of Neutral Current interactions in 1973.

- Soon after NC discovery, Rajaji and KVL Sarma wrote the first model independent analysis of DIS data- called master equations by Sakurai. Series of papers followed which led to the complete determination of NC coupling constants.
- 70's decade was a very productive one, Rajaji et al worked on the phenomenology of the Electro-Weak model which became the Standard Model with the addition of QCD.
- *Rajaji felt he could not contribute substantially to the early development of E-W gauge theory-"Although I missed being on the stage, I sat on the front row".There was no bitterness!*

Rajaji's father was very ill in the early years of 70's which must have affected him- he never gave this as an excuse.

Bump in Hawaii!

"I spent two months in '74 in Hawaii under invitation from Sandip and met San Fu(Tuan). . . . . one day in November we heard on the radio the news of announcement of narrow resonances in e+e- collisions at 3.1 GeV. We did not have any peace over the next few days as San Fu bombarded us with questions and comments until we had exhausted all possibilities of explaining the data, and making us exhausted as well! He was only satisfied when the paper was ready.It was one of the (earliest of) many similar papers. It contained an exhaustive list of interpretations including the correct one." Excerpted from Rajaji's autobiography.

Madras University 1976-84: ICQ vs FCQ!

During 1975-82 Rajaji and his collaborators (S.D. Rindani in particular) extensively worked on integrally charged quark model (ICQ). Many papers were written on constructing observational tests to distinguish between FCQ and ICQ (20 papers.)

- Equivalence of Parisi Model with confinement in QCD (VS, MSS)
- The remarkable properties of broken-colour QCD with integrally-charged quarks(GR,PR).
- Tests of non-standard QCD in a variety of "jet" experiments-steadily uncovered one loop-hole after another in the experimental tests cited in support of the Standard QCD. (TJ,LB, SDR)
- Discovery of new effects invalidating the time-honoured Equivalent Photon Method, for the production of charged particles of spin greater than 1/2 (TJ,SDR) .

With Probir Roy, Lakshmi Bala, T Jayaraman, S.D.Rindani, V. Srinivasan, M.S. Sriram, J.K. Bajaj, S Pakvasa, ...

IMSc-1984-2023: Neutrino Physics

- After the discovery of neutrino oscillations, Rajaji et al (MVN, MN, US) were the first to do a comprehensive realistic 3-generation analysis of the Solar and Atmospheric data to pin down the range parameters– Extended to day-night effect with Solar neutrinos. (KRSB, RS)–Supernova neutrino emission(GD, DI, MVN) in late 90's.
- A very important and notable contribution at this time was the analysis, within the three neutrino framework, of the CHOOZ reactor neutrino data in 1997. They showed that the 3rd mixing angle was $< 12^o$–(not realised by the experimenters initially). Confirmed by Daya Bay and RENO experiments in 2012 ($\approx 9^0$). Implications for CP Violation in the lepton sector and mass hierarchy. (MN, US)

Gautam Dutta, D Indumathi, M V N Murthy, KRS Balaji, Mohan Narayan, Rahul Sinha, Uma Sankar

A4 Symmetry...

- A model for the neutrino mass matrix based on A4 symmetry, a very popular model in neutrino physics (Ma).
- A new mechanism for generating neutrino masses; Higgs as a composite (PPD).
- RG evolution of neutrino parameters (MKP, RNM, SKA, ...)
- In the 60's/70's many anomalous events were observed in KGF- so called Kolar events. Initially Rajaji (KVL)interpreted this as due to the production and decay of a new particle with mass in few GeV range. No such particle was found. Recently, these events were reinterpreted as the decays of possible dark matter particles (MVN) – proposed an experiment at INO to confront this hypothesis (VMD,DI,MVN,BSN). Still many problems with such an interpretation!

Earnest Ma, PP Divakaran, MK Parida, RN Mohapatra, SK Agarwalla, M V N Murthy, VM Datar, D Indumathi, B Satyanarayana

Quantum Statistics and other contributions

- Rajaji (AKM)– discovered many new forms of quantum statistics (such as ortho-statistics, null statistics, etc.). Their theory of generalized Fock spaces enlarged the framework within which familiar quantum field theory and statistical mechanics reside. These may have some significance for non-commutative spaces, Quantum Gravity etc (1991 onwards).
- Unified treatment of Aharanov-Bohm effect(EM)/Collela-Overhauser effect(Gravity) in Kaluza-Klein theory- extended to include Berry phase (RP, RV).
- Consequences of non-commutative Standard Model for physical processes (PKD, NGD, SKG, TS)

AK Misra, R Parthasarathy, R Vasudevan, PK Das, NG Deshpande, SK Gard, T Shreecharan,...

Rebuilding IMSc

- Prof.Alladi Ramakrishnan, Founder of IMSc, retired in 1983- IMSc was looking for a new director. A committee (VCK, BMU, MSN) proposed Rajaji for the post of director.
- Unfortunately a change came about and Rajaji was requested by Ramanna to take over as the Joint Director (not Deputy Director): "During the Director's absence the joint director shall have full powers of the Director".
- Rajaji agreed reluctantly, and along with Prof. Seshadri went about "rebuilding" IMSc.

IMSc 1984-88

- Using his contacts with C Aranganayakam, Education Minister, and VC Kulandaiswamy of Anna University obtained land for Hostel and Guest House in quick time.
- Shift to Central Government Salary structure and service benefits to Faculty as also to administrative members.
- Within four years the faculty strength went from 12 to 31 attracting brilliant young minds in Mathematics and Theoretical Physics from all across the country and abroad.
- Laid the foundation for a graduate school at IMSc which has flourished over the years.
- For the first time, an MSc (Research) program for post-BSc students was organised with help from Anna University and its VC, Kulandaiswamy.
- Starting of Theoretical Computer Science Research program with young faculty members.

Rajaji Fest

Rajaji retired, formally, from IMSc in February 2001, but continued to work as Emeritus Professor till the end. Most of this period was consumed by efforts at creating a world class underground observatory. This is still a work in progress.

Rajaji Fest was a celebration of Rajaji's life in science. Many of his close friends and collaborators came from all over the world to attend. Messages came from Dalitz and others who could not come.

Neutrino Observatory

India was a pioneer in neutrino experiments- one of the first underground laboratory in the world was at KGF- the very first observation of an atmospheric neutrino event 1965(*). Rajaji argued for the creation of a large new underground lab since 1989 (Thrust area meeting-Shantiniketan)

- The idea got off ground in 2000, he worked tirelessly in all aspects related to INO together with others in IMSc.
- Active participant in science R& D, site survey and selection, especially public outreach.
- He was keen on TN as the location for INO knowing it will have a huge impact on its Southern Districts.
- Extensively travelled the villages and towns close to the site meeting people, giving talks, helping in preparing documents, ...

* Nobel Prize is given to the observation of Solar, Supernova, reactor and laboratory neutrinos; Atmospheric neutrinos missing!!

It was not to be!

Initial support from the TN Government ($<$ 2012) turned to apathy ($>$ 2015) and finally evaporated (2020) after more than two decades of work from nearly a hundred scientists, Engineers, Students and even many officials who supported the project.

Contributions to Other Institutions

- While working in Madras University, he was the head of the Department of Theoretical Physics from 1977-80.
- In-charge of the Physics Group and Physics Teaching at Chennai Mathematical Institute (since 2002-).
- Served on Governing Councils of National Institutions, Syndicates of Universities.
- Served on many committees of Science Academies. DAE/DST/UGC, institutions.

He was elected fellow of all the three academies, recipient of Meghnad Saha award and S N Bose Medal of INSA.

Teaching and public outreach

Apart from regular teaching in TIFR/Madras University/IMSc/CMI, Rajaji was involved in multifold activities.

- Running and teaching in the most successful DST-SERC schools in THEP for more than 10 years (with N Mukunda) –forerunner to SERC schools in other subjects.
- Initiated Physics Teaching for Talented students (PTTS).
- Sunday classes with M V Satyanarayana (Pondicherry Un.)- completed 25 years catering to students from TN and Andhra.
- Refresher courses in TN, Kerala, Karnataka, ..through the Academy of Sciences.
- Public outreach for INO for more than 15 years in far flung places in the South.
- Contributed articles in Tamil every month for the Tamil magazine ... Edited by Dr. Jeyapragasam (Now available as books).

Eternal Optimist

Rajaji was an eternal optimist. He believed that the Underground Lab project will be built. Apart from directly working for the physics goals of the ICAL detector(DI,NS,MVN), he also attended every meeting of the TinTin (NDBD) collaboration, Dark Matter collaboration, and even the futuristic Laser Plasma Accelerator discussions.

He and C V K Baba were involved in bringing many, even from outside India, to collaborate with the Indian groups.

Was extremely keen on Universities participating and even taking lead in many projects moving away from few research institutes.

More importantly wanted mega projects in science to take off, especially in remote areas to inspire students locally to take to science and contribute to growth of science and technology in the country!

Rajaji has been an inspiring and leading member of Physics community in India. He lived an honest, candid and a simple life in science and in every thing.

Sources

MY INWARD BOUND JOURNEY

G Rajasekaran

Chennai, May 30, 2021

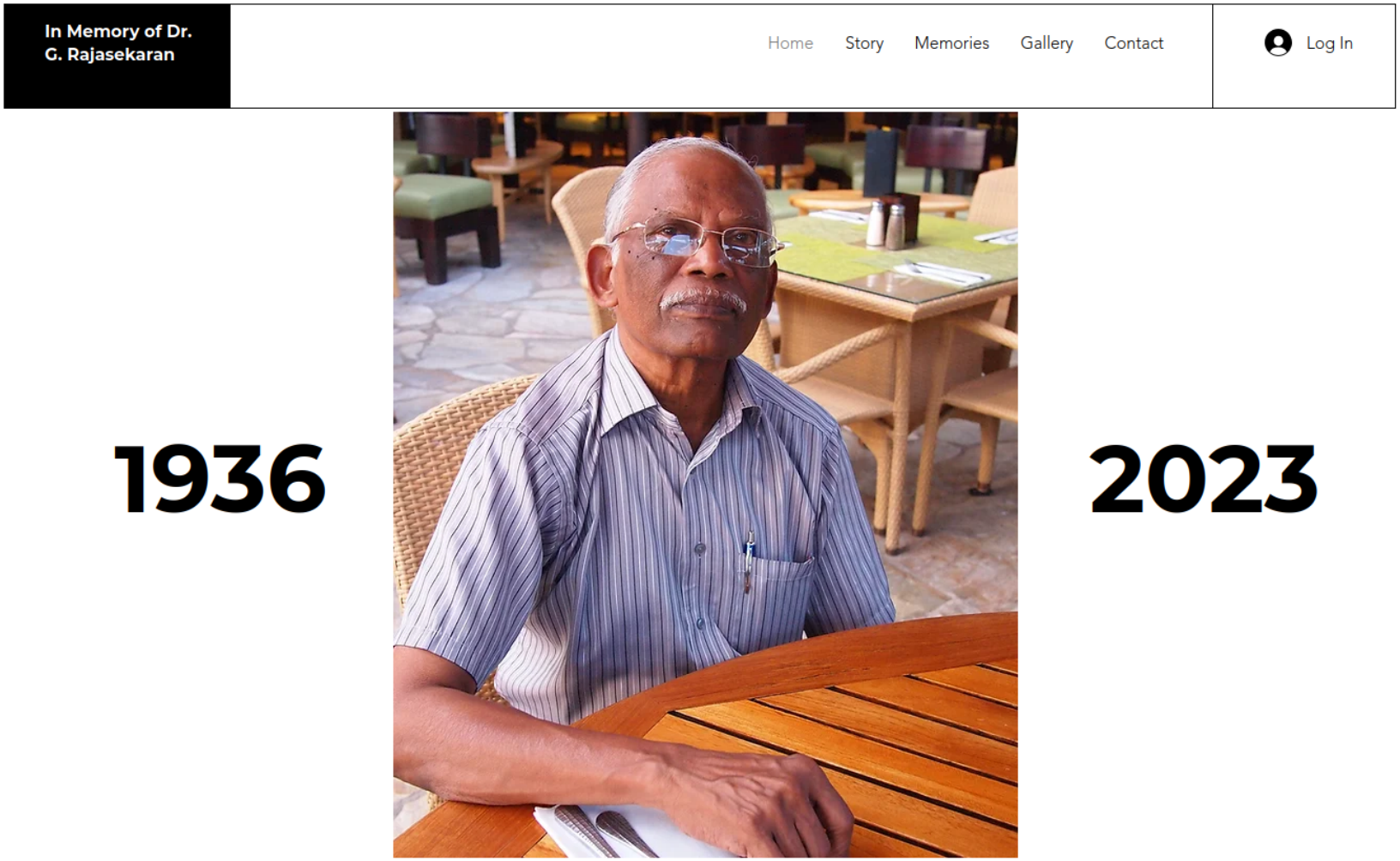
Autobiography of Rajaji available at

https://books.google.co.in/books/about/MY_INWARD_BOUND_JOURNEY.html?id=9h-CEAAAQBAJ&redir_esc=y;

Rajaji Fest proceedings–

https://www.imsc.res.in/xmlui/bitstream/handle/123456789/83/matscirep-119.pdf?sequence=1&isAllowed=y

Memorial website



`https://www.dr-g-rajasekaran.com/`

You are welcome to add your stories, memories, photos to the website.

Thank you for listening!

Mundur V N Murthy