

# 50 Top Indian Physicists

## 1. C.V. Raman (1888-1970), *Nobel laureate*

**Born:** Tiruchirappalli, Tamilnadu.



Chandrashekhara Venkata Raman is India's best known scientist. He is remembered for his revolutionary contribution to physics, known as the '**Raman Effect**'. C.V.Raman was born at Tiruchirappalli in Tamilnadu on November 7th, 1888. His father was a lecturer in mathematics and physics. Raman studied at Presidency College, Madras, and passed his B.A. examination in 1904, winning the gold medal in physics; and in 1907 he gained his M.A. degree, obtaining the highest distinctions.

Raman joined the Indian Finance Department in 1907 and he was posted in Calcutta. In his spare time Raman found opportunities for carrying on experimental research in the laboratory of the Indian Association for the Cultivation of Science at Calcutta. In 1917 he was offered the newly endowed Palit Chair of Physics at Calcutta University, and he accepted it. After 15 years at Calcutta he became Professor at the Indian Institute of Science at Bangalore (1933-1948), and from 1948 he was the Director of the Raman Institute of Research at Bangalore, established and endowed by himself. He also founded the Indian Journal of Physics in 1926, of which he was the Editor.

Optics and acoustics were the two fields of investigation to which he had dedicated almost his entire career. Studying the scattering of light in various substances, in 1928 he found that when a transparent substance is illuminated by a beam of light of one frequency, a small portion of the light emerges at angles other than the original direction, and some of this light is of different frequencies than that of the incident light. These so-called Raman frequencies are the energies associated with transitions between different rotational and vibrational states in the scattering material. This discovery known as Raman effect won him the *Nobel prize for physics in 1930*.

One of Raman's interests was understanding the physics of musical sounds. He worked out the theory of transverse vibration of bowed string instruments. His other interests included the optics of colloids, electrical and magnetic anisotropy, and the physiology of human vision.

He was also awarded the Hughes Medal in 1930, the Bharat Ratna in 1954 and the Lenin Peace Prize in 1957. He was elected as a Fellow of the Royal Society (FRS) in 1924 and was knighted by the British government in 1929.

## **2. S. Chandrasekhar (1910-1995), Nobel laureate**

**Born: Lahore, British India, now in Pakistan**



Subrahmanyan Chandrasekhar was an astrophysicist, best known for his work on the theoretical structure and evolution of stars, and particularly for his theory of the '**Chandrasekhar Limit**'. He won the *Nobel Prize in Physics in 1983* largely for this early work, although his research also covered many other areas within theoretical physics and astrophysics. Chandrasekhar worked in various fields like the quantum theory on the hydrogen anion, radiative transfers, theory of white dwarfs and stellar dynamics. He did important work on energy transfer by radiation in stellar atmospheres and convection on the solar surface. He also attempted to develop the mathematical theory of black holes, describing his work in the book, "*The Mathematical Theory of Black Holes*" (1983).

Chandrasekhar was born in Lahore (then a part of British India). His father, Chandrasekhara Subrahmanya Ayyar, an officer in the Indian Audits and Accounts Department, was then in Lahore as the Deputy Auditor General of the Northwestern Railways. Chandrasekhar studied at Presidency College, Madras from 1925 to 1930. Thereafter, he was awarded a Government of India scholarship for graduate studies in Cambridge, England. In Cambridge, he became a research student under the supervision of Professor R.H. Fowler. On the advice of Professor P.A.M. Dirac, he spent the third of his three undergraduate years at the Institut för Teoretisk Fysik in Copenhagen.

Chandrasekhar joined the University of Chicago in the USA as an assistant professor

in 1937. He was to remain at the University of Chicago for his entire remaining career, a total of 58 years. He did some of his work at the University of Chicago's Yerkes Observatory, and, later, at NASA's Laboratory for Astrophysics and Space Research which was built at the University in 1966. During World War II, he worked at the Ballistic Research Laboratories at the Aberdeen Proving Ground in Maryland.

Chandrasekhar was conferred with the Padma Vibhushan by the government of India in 1968 and was also the Fellow of the Royal Society. C.V. Raman was his paternal uncle.

### **3. S.N.Bose (1894-1974)**

**Born: Kolkata, West Bengal**



Satyendra Nath Bose was Indian mathematician and physicist noted for his collaboration with Albert Einstein in developing the theory of Bose-Einstein statistics. S.N. Bose contributed to statistical mechanics, the electromagnetic properties of the ionosphere, the theories of X-ray crystallography and thermoluminescence, and unified field theory. Bose's paper, Planck's Law and the Hypothesis of Light Quanta (1924), led Einstein to seek him out for collaboration.

Satyendra Nath Bose's name is immortalised in physics through the fundamental terms like, '*Bose-Einstein statistics*', '*Bose-Einstein Condensate*' and '**Boson**'. Bose was a polygot and his interests were spread in various fields in science, arts and mathematics. Rabindranath Tagore dedicated his book *Visva Parichay*, his only science book, to Bose.

S.N.Bose was a graduate of the University of Calcutta. He completed the master's degree in Applied Mathematics at the University of Calcutta in 1915. He also learned enough German and French to read scientific works published in these languages. In 1921, Bose joined the teaching faculty of physics department at the University of Dhaka, and went on to establish new departments, laboratories and libraries. He taught at the University of Dacca during the years 1921–45 and then at University of Calcutta during 1945–56. Bose published numerous scientific papers 1918 to 1956 and contributed to the development of modern physics.

He wrote his famous paper in 1924 in which he derived Planck's quantum radiation law without reference to classical physics—which he was able to do by counting states with identical properties. The paper would later prove seminal in creating the field of quantum statistics. Bose sent the paper to Einstein in Germany, and the great scientist recognized its importance, translated it into German and submitted it on Bose's behalf to the prestigious scientific journal *Zeitschrift für Physik*. The publication led to recognition, and Bose was granted a leave of absence to work in Europe for two years at X-ray and crystallography laboratories, where he worked alongside Einstein and Marie Curie, among others.

S.N. Bose was conferred with the Padma Vibhushan in 1954 and was elected as a Fellow of the Royal Society.

## 4. Meghnad Saha (1893-1956)

**Born : Seoratali, Dacca, Bangladesh**



An internationally acclaimed astrophysicist, Meghnad Saha was known for the '*Saha ionization equation*'. Saha was also popular for his other notable scientific works and his contribution to building several scientific institutions. Saha was the chief architect of river planning in India and prepared the initial plan for the Damodar Valley Project.

After passing the Intermediate Examination of the Calcutta University in 1911 from the Dhaka College, Dhaka, Saha joined the Presidency College at Kolkata. Among his classmates was Satyendranath Bose, of the Bose-Einstein Statistics fame. Saha passed his BSc Examination with Honours in Mathematics in 1913 and MSc (Applied Mathematics) Examination in 1915. Saha was appointed lecturer in the Department of Applied Mathematics in 1916 in the University College of Science.

Saha's theory of thermal ionisation, which explained the origin of stellar spectra, was an epoch-making discovery. It ranks as one of India's most important contributions to world science in the early 20th century. Arthur Stanley Eddington, described Saha's theory of thermal ionisation as the twelfth most important landmark in the history of astronomy. Saha made important contributions in different branches of physics. It was Saha who first started the teaching and training in nuclear physics in the country. The first cyclotron in the country was built with Saha's initiatives. Saha was a great institution builder. Among the institutions that he built were: National Academy of Sciences, at Allahabad, Indian Physical Society, Kolkata, National Institution of Sciences of India (which was later renamed Indian National Science Academy), New Delhi, Indian Science News Association, Kolkata, and Saha Institute of Nuclear Physics, Kolkata.

Saha was an active member of the National Planning Committee constituted by the Indian National Congress in 1938 with Jawaharlal Nehru as its Chairman. He was the Chairman of the Indian Calendar Reform Committee constituted by the Council of Scientific and Industrial Research (CSIR) in 1952. He was an elected Independent Member of the Indian Parliament. He advocated large-scale industrialisation for social development. Saha was also a Fellow of the Royal Society.

## **5. Jagadish Chandra Bose (1858-1937)**

**Born: Bikrampur, Bengal, (now in Bangladesh)**



The scientific life of Acharya Jagadish Chandra Bose is unique due to his colossal contributions in both physical and biological sciences.

J.C. Bose was born in a Bengali family in Munsiganj (Bikrampur), Bengal Presidency of British India. His father, Bhagawan Chandra Bose, was a leading member of the Brahmo Samaj. In 1875, he was admitted to St. Xavier's College, Calcutta. At St. Xavier's, Bose came in contact with Jesuit Father Eugene Lafont, who played a significant role in developing his interest in natural

sciences. He received a BA from the University of Calcutta in 1879. Bose went to England to study Medicine at the University of London. However, he had to quit because of ill health. Afterwards he secured admission in Christ's College, Cambridge to study natural sciences. He received a BA (Natural Sciences Tripos) from the University of Cambridge and a BSc from the University College London affiliated under University of London in 1884, and a DSc from the University College London in 1896. Returning to India, he was appointed professor of physical science at Presidency College, Calcutta. In 1917 Bose left his professorship and established the Bose Institute at Calcutta which was initially devoted principally to the study of plants. He was its director for twenty years until his death.

Jagdish Chandra Bose, designed and made a very sophisticated instrument called the crescograph, which could record and observe plants minute responses to external stimulants. It was capable of magnifying the motion of plant tissues to about 10,000 times of their actual size and, in doing so, found many similarities between plants and other living organisms.

Bose's experiments on the quasi-optical properties of very short radio waves (1895) led him to make improvements on the coherer, an early form of radio detector, which have contributed to the development of solid-state physics. Bose's Galena detector was the first semiconductor device and photovoltaic cell. He also designed the earliest waveguide and Horn Antenna, an integral part of present day microwave engineering and astronomy.

In 1895, he was the first to demonstrate the wireless transmission and reception of electromagnetic waves at Presidency College (now Presidency University), Kolkata.

## **6. K. S. Krishnan (1898-1961)**

**Born: Watrap, Tamilnadu, India**

Sir Kariamanickam Srinivasa Krishnan, FRS, was a co-discoverer of Raman scattering, for which his mentor C. V. Raman was awarded the Nobel Prize. K S Krishnan was a pioneer in what is now called quantum condensed matter physics. His fundamental contributions to Raman effect, anisotropic magnetic properties of molecules and solids, discoveries of quasi 2 dimensional electron transport and Landau diamagnetism in graphite, theory and experiments on the electron transport in alloys (*Krishnan-Bhatia formula*) and other phenomena gave credence to the then emerging field of quantum theory of matter.

K.S.Krishnan attended the American College in Madurai and the Madras Christian College, Chennai. After gaining his degree in Physics he became a demonstrator in chemistry. In 1920, Krishnan went to work with C.V. Raman at the Indian Association for the Cultivation of Science, Kolkata. In 1928, Raman along with Krishnan discovered 'Raman effect'. In December 1928 K.S.Krishnan moved to the Dacca University (now in Bangladesh) as the Reader of in the physics Department. At the time Satyendra Nath Bose was the Head of the Physics Department there. In Dacca University he studied magnetic properties of crystals in relation to their structure. In the process Krishnan developed elegant and precise experimental technique to measure the magnetic anisotropy of dia and paramagnetic crystals. The research papers published by Krishnan and his colleagues from Dacca University are considered to be foundation stones of the modern fields of crystal magnetism and magneto chemistry.



In 1933 K.S.Krishnan came back to Kolkata to take up the post of Mahendralal Sircar Professor of Physics in the Indian Association for the Cultivation of Science. In 1937, KSKrishnan was invited by Rutherford to the Cavendish Laboratory, Cambridge, and by W. L.Bragg to the Royal Institution, London, to give lectures. In 1942, K.S.Krishnan moved to Allahabad University as Professor and Head of the Department of Physics. Here he took up the physics of solids, in particular metals.

KSKrishnan played an important role in the development of science and technology in India. He was deeply associated with the premier scientific/educational organizations in the country like the Atomic Energy Commission, the Council of Scientific and Industrial Research and the University Grants Commission. Impressed by his remarkable contributions in the field of science, Nehru appointed him as the first director to run the National Physical Laboratory (NPL), India's first national laboratory, which was set up in 1948.

In 1940, he was selected for the prestigious fellowship of the Royal Society. He was conferred with Padma Bhushan in 1954, and he was the first Indian to get the Bhatnagar Award in 1958. He was Knighted in 1946. In 1956, he was elected a Foreign Associate of the US National Academy of Sciences.

## **7. Radha Gobinda Chandra (1881-1975)**

**Born: Jessore , Undivided Bengal , British India.**



Radhagobinda Chandra was a pioneer of observational astronomy in India. Radha Gobinda is especially famous for his observation of variable stars. He observed more than 49,700 variable stars and became one of the first international members of American Association of Variable Star Observers.

Radhagovinda Chandra was born in Bagchar village of Jessore district in Bengal. After getting primary education in the local school, Radhagovinda was enrolled in the Zila School as a secondary level student. But he got married to a 9-year old girl named Govinda Mohini at the age of 21 in 1899 before completing the school. Later, his attempts to continue formal education were unsuccessful. But he became self taught in astronomy, acquired considerable knowledge in Mathematics, English and Persian.

Radhagovinda obtained a government job at a lower level. He used to observe the sky during night after finishing the daily routine job. He observed the Hally's comet appeared in the sky of Bengal in 1910 by an ordinary binocular. He wrote a series containing the findings of the two month long observation, and it was published in a Bengali periodical. After that, he purchased a small telescope. In June 1918, he observed and identified the Nova Star Aquila-3 and marked his name in the history of astronomey. Radhagovinda sent his report to Dr. Edward Pickering, Director, Harvard College Observatory. Dr. Pickering was so much impressed with the report that he inducted Radhagovinda in the American Association of Variable Star Observers (AAVSO) as a member. In 1926

The Association loaned him a 6-inch telescope donated by Charles W. Elmer. In 1928 Chandra received the French *Officer d'Academic* Brevet and Badge for his astronomical work. Between 1920 and 1954, Chandra reported a total of 37,215 observations. The Elmer telescope later passed to M. K. Vainu Bappu and it has been kept in the Kavalur space observatory. The value of Radha Gobind Chandra's prodigious work lies in the fact that he worked at a longitude far from that of most observers, greatly improving the temporal completeness of the observational records for the stars he observed.

## **8. S.K. Mitra (1890-1963)**

**Born: Kolkata, Bengal, India**

**Sisir Kumar Mitra** is the doyen of radio science in India. He is known for his seminal work on ionosphere. The first experimental evidence of E-region of the ionosphere was obtained by Mitra and his coworkers in 1930. In the moon a crater is named 'Mitra' after him.



**Sisir Kumar Mitra** pursued a B.Sc and completed his M.Sc in physics from the Presidency College in Kolkata in 1912 and later worked as a research scholar under Jagadish Chandra Bose. In 1916, he was invited to work as a post-graduate research scholar in physics under the guidance of C.V. Raman.

Mitra worked with Raman on light diffraction. He received his D.Sc from Calcutta University in 1919 for his thesis on 'The interference and diffraction of light', and then moved to the University of Paris to work on his second doctorate on copper wavelength standards. Here, he worked under Charles Fabry, a light interference expert who had studied the upper atmosphere. Fabry was also the co-discoverer of the ozone layer of the earth, which exists in the upper atmosphere.

He also worked under Marie Curie for a short period of time at the Radium Institute (now Curie Institute) in Paris before deciding to study the new and emerging concept of radio com-

munications. Mitra went to the University of Nancy in France later to work under Camille Gutton, who helped develop the radar and was a leading authority in radio electricity.

In 1923, he was offered the Khaira Chair of Physics in the University of Calcutta. On returning to India Mitra started to teach wireless at the postgraduate level in the University College of Science. Soon afterwards, the subject was introduced into the M.Sc. physics course at the University and the Wireless Laboratory was set up in 1925. The first research was concerned with the measurement of atmospherics; a little later an ionosonde was built and was used for investigating the ionosphere above Calcutta. This same apparatus was used during the second International Polar Year 1932-1933, as part of an international programme of ionospheric observations

Mitra's group could measure the heights of the different layers of the ionosphere by an instrument designed and built indigenously. The investigations carried out by Mitra's laboratory not only provided the first general picture of the ionospheric condition in a sub-tropical region of low altitude like Calcutta but experimental results obtained by Mitra and his coworkers also threw considerable light on the effect of thunderstorm, magnetic storm and meteoric shower on upper atmospheric ionization. Mitra also gave a theory of the D-layer which was first reported by Appleton in 1928

The acclaimed radio physicist is known for his treatise *The Upper Atmosphere* (1947), which details his contributions to the field of ionospheric studies. The treatise went on to be internationally recognised and has since been translated into multiple languages.

Mitra was elected a Fellow of the Royal Society, London in 1958 for his contributions to the study of upper atmospheric phenomena. He was awarded the Padma Bhushan in 1962.

## **9. Homi J. Bhabha (1909-1966)**

**Born: Mumbai, Maharashtra**

Homi Jehangir Bhabha is referred as the 'father of Indian Nuclear Programme'. He founded two of India's most prestigious research institutions; the Tata Institute of Fundamental Research (TIFR) and the Trombay Atomic Energy Establishment, which was renamed to Bhabha Atomic Research Centre (BARC). He is known for studying the process of '*Bhabha Scattering*', which is an electron-positron scattering process.

Homi Bhabha was born to a wealthy family in Mumbai. In 1927, he went to England at Cambridge University. Although he began studying engineering per the wishes of his family, Bhabha was quickly drawn to physics. Bhabha at the Cavendish Laboratory and earned his Ph.D. in nuclear physics in 1934.

At the behest of physicist Sir Chandrasekhara Venkata Raman, director of the Indian Institute of Science, Bangalore (Bengaluru), he joined the institute as a reader in physics in 1940. In the following year, he was promoted to Professor of Cosmic Ray Research.



In April 1948, eight months after India gained independence from British rule, Bhabha sent a note to then Prime Minister Jawaharlal Nehru, proposing the formation of an Atomic Energy Commission that would direct the development of India's nuclear energy program for peaceful purposes. The proposal received Nehru's blessings, and the commission was established by an act of parliament in August of the same year. Bhabha was made Chairman of the commission. Bhabha also played a crucial role in the development of electronics in India. Bhabha was a person with sensitive and trained artistic gifts of the highest order.

Bhabha was an outstanding scientist and a brilliant engineer. He derived a correct expression for the probability of scattering positrons by electrons, a process now known as Bhabha scattering. His classic paper, jointly with W. Heitler, published in 1937 described how primary cosmic rays from space interact with the upper atmosphere to produce particles observed at the ground level. Bhabha and Heitler explained the cosmic ray shower formation by the cascade production of gamma rays and positive and negative electron pairs. 'In 1938 Bhabha was the first to conclude that observations of the properties of such particles would lead to the straightforward experimental verification of Albert Einstein's theory of relativity'.

Bhabha's contribution to the development of atomic energy made him a significant figure in international scientific circles. He served as president of the United Nations Conference on the Peaceful Uses of Atomic Energy in 1955 and as president of the International Union of Pure and Applied Physics from 1960 to 1963.

Bhabha was killed in an air-crash near the famous Mont Blanc peak of the Alps on January 24, 1966, while he was on his way to Vienna to attend a meeting of the Scientific Advisory Committee of the International Atomic Energy Agency. At the time of his death, Bhabha was Director and Professor of Theoretical Physics of the Tata Institute of Fundamental Research, Secretary to the Government of India in the Department of Atomic Energy, ex-officio Chairman of the Indian Atomic Energy Commission, and Director of the Atomic Energy Establishment at Trombay.

Bhabha was a Fellow of the Royal Society and was awarded with the Adams Prize in 1942 by the University of Cambridge and the Padma Bhushan in 1954. Bhabha died in a plane crash near Mont Blanc in January 24, 1966.

## 10. Bibha Chowdhuri (1913-1991)

**Born: Kolkata, Bengal, India**



Bibha Chowdhuri was an Indian physicist who did pioneering work on particle physics and cosmic rays. Chowdhuri was born in Kolkata. Her father, Banku Behari Chowdhuri, was a doctor. Her mother's family were adherents of the Brahmo Samaj movement. Bibha studied physics at the Rajabazar Science College of Calcutta University and was the only woman to complete M.Sc. degree in the year 1936. She joined the Bose Institute and worked with Debendra Mohan Bose. As a student of D.M. Bose, she studied cosmic ray showers during 1938-1942 in Darjeeling. After meticulously exposing and observing half-tone photographic plates, she found new tracks created by a new subatomic particle with 200 times the electronic mass. This was the previously unidentified particle, now called pion.

The results were published in *Nature*. Chowdhuri and Bose could not access full-tone photographic plates because World War II was raging at the time. Using the same technique, but with high quality full-tone photographic plates, the British physicist, Cecil Frank Powell, identified the pion at least four years later and won the Nobel Prize in 1950. Powell acknowledged Bose and Chowdhuri's pioneering contribution in his work.

In 1945, Bibha Chowdhuri joined "the cosmic ray laboratory of would-be Nobel Laureate P.M.S. Blackett (he was awarded the Nobel Prize in 1948) for her PhD at a time when studies on extensive air showers in cosmic rays were one of the most important investigations in particle physics". It is unclear how much her work contributed to Blackett's Nobel Prize.

Chowdhuri returned to India after her PhD. On her return, she joined TIFR. After eight years, she joined the Physical Research Laboratory (PRL) at Ahmedabad. She was involved deeply with the Kolar Gold Mine experiment. In 1954 she was a visiting researcher at the University of Michigan. Later she moved to Kolkata to work at the Saha Institute of Nuclear Physics.

The International astronomical Union (IAU) has re-christened the star HD 86081 as Bibha (a yellow-white dwarf star in the constellation Sextans south of the celestial equator) as a way of honouring Bibha Chowdhuri.

## **11. R. S. Krishnan (1911-1999)**

**Born: Thrissur, Kerala, India**

**Rappal Sangameswaran Krishnan** was an experimental physicist and scientist. He is known for his pioneering researches on colloid optics and the discovery which is now known as **Krishnan Effect**.

R.S.Krishnan completed his bachelor's degree with honours (BA Hons.) and a first rank in 1933, from St. Joseph's College, Tiruchirappalli. He subsequently joined the Indian Institute of Science, Bangalore as a research student under Nobel laureate Sir C. V. Raman. For his research, he received a doctorate from the University of Madras (DSc) in 1938.



In 1938, he became a researcher at Cavendish Laboratory of Cambridge University under Sir John Cockcroft. His researches at Cambridge is reported to have assisted in the development of the 37' Cyclotron and to the observation of deuteron-induced fission in uranium and thorium. The University awarded him PhD, in 1941. He conducted his thesis research under Norman Feather, a colleague of John Cockcroft's and also a student of Lord Rutherford.

Krishnan returned to India the same year and joined the Physics department of the Indian Institute of Sciences, Bangalore in 1942, where he returned to work under C.V. Raman's

tutelage. After the retirement of Raman, Krishnan succeeded him as the Head of the Department of Physics in 1948. He served the institution till 1972 and, on his superannuation, he was appointed as the vice chancellor of the University of Kerala, Thiruvananthapuram in 1973 and held the position till 1977.

Working further on the Raman Effect, Krishnan discovered the reciprocity relations between the intensity of the horizontally polarised incident light getting scattered with horizontal polarization irrespective of the colloidal particles; this is known as Krishnan (reciprocity) Effect. He is credited with researches on Second Order Raman Spectra in diamond and in alkali halide crystals and is reported to have successfully recorded the phenomena for the first time, using the ultraviolet (mercury 2536 Å) technique of excitation for Raman spectroscopy, a technique he developed. This is known to have provided confirmation of Born's lattice dynamical theory. He was the first scientist to perform Brillouin scattering experiments in diamond, crystalline and fused quartz, alumina and alkali halides and is the author of a theory on Brillouin scattering in cubic and birefringent crystals. Krishnan also had initiated efforts on dating of Indian rock formations using nuclear geochronological techniques. He was the author of a monograph, two volumes of '**Source Book on Raman Effect**'.

K.S.Krishnan served as a member of the International Committee on Ferro-electricity and sat in the International Advisory Committee for Conferences on Raman Spectroscopy, he represented India in several international conferences and seminars such as the 2nd International Conference on Crystallography in Stockholm in 1951, the International Science Conference at Edinburgh, the 5th Australian Spectroscopic Conference, and the 1st International Conference on Raman Spectra on Crystals in Paris

## **12. Vikram Sarabhai (1919-1971)**

**Born: Ahmedabad, Gujarat, India**

Vikram Ambalal Sarabhai, was an Indian physicist who initiated space research and helped develop nuclear power in India. Vikram Sarabhai was a great institution builder and established or helped to establish a large number of institutions in diverse fields. He was instrumental in establishing the Physical Research Laboratory (PRL) in Ahmedabad.



Vikram Ambalal Sarabhai is regarded as the father of India's space programme. He was one of key people in the establishment of the Indian Space Research Organization (ISRO).

Sarabhai was born into a family of industrialists. He attended Gujarat College, Ahmadabad, but later shifted to the University of Cambridge, England, where he took his tripos in natural sciences in 1940. Returning to India, he undertook research in cosmic rays under physicist Sir C.V. Raman at the Indian Institute of Science, Bangalore. In 1945 he returned to Cambridge to pursue a doctorate and wrote a thesis, "Cosmic Ray Investigations in Tropical Latitudes". He founded the Physical Research Laboratory in Ahmadabad in 1947, on his return to India.

Homi Jehangir Bhabha, supported Sarabhai in setting up the first rocket launching station in India. This center was established at Thumba near Thiruvananthapuram on the coast of the Arabian Sea, primarily because of its proximity to the equator. Later, Sarabhai started a project for the fabrication and launch of an Indian Satellite. As a result, the first Indian satellite, Aryabhata, was put in orbit in 1975 from a Russian Cosmodrome. The Thumba centre has now grown into a large facility under ISRO and is named as Vikram Sarabhai Space Centre (VSSC).

Sarabhai was very interested in science education and founded a Community Science Centre at Ahmedabad in 1966. Today, the Centre is called the Vikram Sarabhai Community Science Centre.

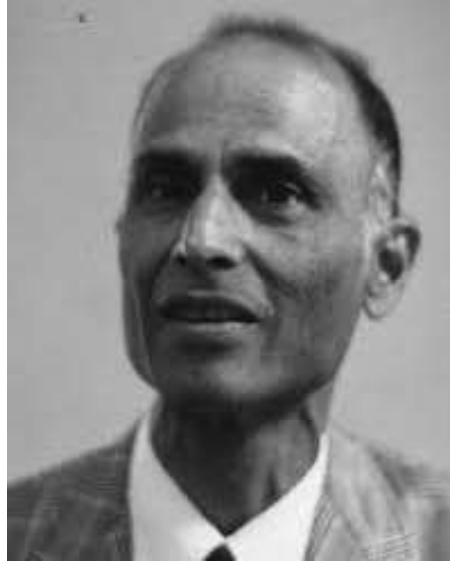
The range and breadth of Sarabhai's interests were remarkable. In spite of his intense involvement with scientific research, he took active interest in industry, business, and development issues. Realizing the need for professional management education in India, Sarabhai was instrumental in setting up the Indian Institute of Management in Ahmadabad in 1962.

He was awarded the Padma Bhushan in 1966 and the Padma Vibhushan posthumously in 1972. He was married to Mrinalini Sarabhai, a renowned classical dancer from Kerala.

## **13. Harish Chandra (1923-1983)**

**Born: Kanpur, Uttar Pradesh**

Harish Chandra was an Indian-American scientist known for his contribution in physics and mathematics. Harish-Chandra was educated at B.N.S.D. College, Kanpur and at the University of Allahabad. After receiving his master's degree in Physics in 1943, he moved to the Indian Institute of Science, Bangalore for further studies in theoretical physics and worked with Homi J. Bhabha.



After a short while, Harish-Chandra went to Cambridge, where he studied for his Ph.D. under P.A.M.Dirac's supervision. During his time in Cambridge, he moved away from physics, and became more interested in mathematics. Harish-Chandra obtained his degree in 1947 and, in the same year, he went to the USA.

Dirac visited Princeton for one year, and Harish-Chandra worked as his assistant during this time. However, he was greatly influenced by the mathematicians Hermann Weyl and Claude Chevalley. The period from 1950 to 1963 was his most productive, and he spent these years at the Columbia University. During this time, he worked on representations of semisimple Lie groups. Also, during this period he had close contact with André Weil. His fundamental work in the Representation theory made him immensely popular.

Harish-Chandra worked at the Institute for Advanced Study at Princeton from 1963. He was appointed IBM von Neumann Professor in 1968. Harish-Chandra received many awards in his career. He was a Fellow of the Royal Society of London, and a Fellow of the National Academy of Sciences. He won the Cole prize from the American Mathematical Society in 1954 . In 1974, he received the Srinivasa Ramanujan Medal from the Indian National Science Academy.

## **14. G.N Ramachandran (1922-2001)**

**Born: Ernakulam, Kerala**

Gopalasamudram NarayanaIyer Ramachandran, was an Indian physicist known for his outstanding contributions in biology. His most acclaimed achievement is the **Ramachandran plot** for understanding peptide structure. He was also the first to propose a triple-helical model for the structure of collagen. He also made other major contributions in both biology and physics.



G.N. Ramachandran was born in a small town near Cochin in Kerala. His father was a Professor of Mathematics at a local college. Ramachandran graduated in 1942 as the top-ranking student in the B.Sc. (Honors) Physics course of the University of Madras. In the same year he joined the Master's program in Electrical Engineering at the Indian Institute of Science at Bangalore, but was soon brought into the Physics stream by the head of the Physics Department, Sir C.V. Raman. Under the guidance of C.V. Raman, Ramachandran did his post-graduate research in the areas of optics and X-ray topography of diamonds, and obtained a D.Sc. degree in 1947.

In 1947, Ramachandran went to the Cavendish Laboratory in Cambridge, England, then headed by Sir Lawrence Bragg. At Cambridge, he worked with W.A. Wooster and A. Lang on a crystallographic project and developed a mathematical theory for determining the elastic constants of crystals from measurements of diffuse X-ray reflections. He received a Ph.D. from Cambridge University in 1949. While at Cambridge, Ramachandran met Linus Pauling and was deeply influenced by his lectures on modeling studies of polypeptide chains.

In 1952, Ramachandran became a professor of physics at the University of Madras at the age of 29. He did research in X-ray microscopy and crystal physics during his stint as the HOD in Madras University. But, he became increasingly more interested in problems of biology. Ramachandran was the founder of the '*Madras school*' of conformational analysis of biopolymers. His discovery of the triple helical structure of collagen in 1955 and his analysis of the allowed conformations of proteins through the use of the 'Ramachandran plot' rank among the most outstanding contributions in structural biology, along with Pauling's description of the  $\alpha$ -helix and Watson and Crick's discovery of the double helical structure of DNA.

## 15. M.K.Vainu Bappu (1927- 1982)

Born: Chennai, Tamilnadu, India



Manali Kallat Vainu Bappu was an eminent Indian astronomer of international repute. Bappu helped establish several astronomical institutions in India—including the Vainu Bappu Observatory named after him—and also contributed to the establishment of the modern Indian Institute of Astrophysics.

MK Vainu Bappu obtained his PhD degree (1952) from Harvard College, Massachusetts, USA. His specialization was in astronomy. He was Carnegie Fellow, Hale Observatory (1952); and Director of UP State Observatory, Nainital (1954-60); of Astronomical Observatory, Kodaikanal (1960-77), and of Indian Institute of Astrophysics, Bangalore (1977-82).

He was well known for the discovery of the *Bappu-Bok-Newkirk comet* and the **Wilson-Bappu effect**. He made an exhaustive survey of Wolf-Rayet stars, a subject in which he remained an authority throughout his life. He investigated the incidence of H and K emission from ionized calcium in late type stars; the results revealed a relation connecting the equivalent width of the H and K lines with the absolute magnitude of the star. ( Wilson-Bappu effect). This is one of the fundamental relations often used in stellar luminosity determination. His research areas covered: physics of the sun, stars, and solar system; physical phenomena in galactic and extragalactic systems; and astrophysical techniques.

Bappu's indefatigable industry and far-reaching vision led to the founding of the National Observatory in UP (now in Uttranchal), rejuvenated the Kodaikanal Observatory and created the Indian Institute of Astrophysics, Bangalore, and the Observatory at Kavalur, Tamil Nadu. Bappu was an authority on the history of astronomy in India during the British period.

Vainu Bappu was Foreign Member, Royal Society of Science, Liege, Belgium; Honorary Foreign Associate, Royal Astronomical Society, London; Member of Astronomical Society

of India (President, 1973-74). He was a recipient of Donhoe Comet Medal by Astronomical Society of the Pacific (1949); SS Bhatnagar Prize (1971); Padma Bhushan (1981); and Satyendra Nath Bose Medal of INSA (1983) (Posthumously). Thanks to his extensive contribution in the field of astronomy, Bappu earned one of the biggest honours in the astronomical community when he became the President of the International Astronomical Union for the years 1979-1982.

## **16. S. Pancharatnam (1934-1969)**

**Born: Calcutta , West Bengal, India**



Shivaramakrishnan Pancharatnam was an Indian physicist who did significant work in the field of optics. He is noted for his discovery of geometric phase known as **Pancharatnam-Berry phase** for polarized beams passing through crystals.

Pancharatnam joined Raman Research Institute as a Senior Scholar in 1952. He completed his Ph.D. under the guidance of Sir C V Raman. In 1956 Raman appointed him as an Assistant Professor at RRI.

In 1956, Pancharatnam was studying interference figures produced by light waves in crystal plates, under his advisor C. V. Raman, when he discovered the properties of what is now known as the geometric phase, and which predated Michael Berry's work on the topic from 1983. Raman and Pancharatnam also worked on “mirages” and formulated the underlying optical principles. Pancharatnam’s main study however was on Amethyst and then a mineral called Iolite showing unique pleochroism. This work became a classic in crystal optics and Pancharatnam published several papers in the Proceedings of The Indian Academy of Sciences on the subject.

He was elected a Fellow of the Indian Academy of Sciences at the early age of 25. He was a reader at the Department of studies in Physics, University of Mysore from 1961-1964.

From 1964 until his death in 1969 at the age of 35 he was a Research Fellow of St Catherine's College, Oxford, working in association with George William Series. His publications for this period were mainly concerned with the theory of effects found in experiments on atomic physics of optical pumping, e.g. double refraction in a gas due to spin alignment. Professor Series has written an introduction to the life and work of Pancharatnam. He also prepared, for the Proceedings of the Royal Society, the last three papers from notes left by Pancharatnam.

## **17. E. C. George Sudarshan (1931 - 2018)**

**Birthplace: Kottayam, Kerala, India**



Ennackal Chandy George Sudarshan ( known as E. C. G. Sudarshan) was one of India's best known theoretical physicists. Sudarshan has been credited with numerous contributions to the field of theoretical physics, including Glauber–Sudarshan representation, V-A theory, tachyons, quantum Zeno effect, open quantum system and Lindblad equation, spin–statistics theorem, non-invariance groups, positive maps of density matrices, and quantum computation.

He wrote more than 500 scientific papers as well as 10 books on a variety of topics like Classical Dynamics, Quantum Optics, and Philosophy. He worked at the Universities of Rochester, Harvard, Syracuse, the Indian Institute of Science Bangalore, the Institute of Mathematical Sciences Chennai, and the University of Texas where he was a professor for 47 long years.

Ennackal Chandy George (ECG) was born in Kottayam, Kerala. After high school, he completed the two-year Intermediate at the Church Mission Society (CMS) College in Kottayam in 1948. From CMS College, ECG went to the Madras Christian College (MCC) in Chennai for his B Sc (Honours) in Physics(1948 to 1951), after which he stayed on for a year as a demonstrator in physics. In 1952, he received the MA degree of the University of Madras. ECG then joined the Tata Institute of Fundamental Research (TIFR) in Mumbai as a research scholar.

Sudarshan completed his Ph D in 1958 under the guidance of particle physicist Robert Marshak at Rochester University, USA, and then spent two years (1957 to 1959) as Research Fellow

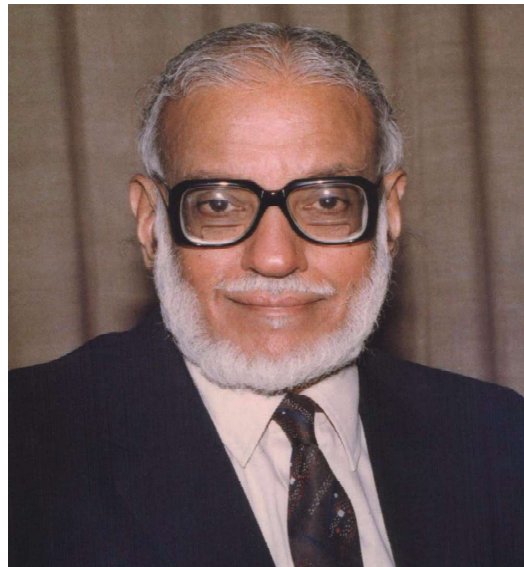
with Julian Schwinger at Harvard University.

By early 1957, after an extensive study of all existing experimental results in particle physics, Sudarshan and Marshak had arrived at the so-called 'V – A' structure for the universal Fermi interaction. This ultimately became the structure on which the edifice of unification of electromagnetic and weak nuclear interactions was built. Three other scientists, Sheldon Glashow, Abdus Salam and Steven Weinberg, developed it further. The three got the Nobel Prize for their work in 1979, but unfortunately Sudarshan and Marshak were not honoured.

The government of India honoured George Sudarshan with Padma Bhushan in 1976 and Padma Vibhushan in 2007.

## **18. M. G. K. Menon (1928 – 2016)**

**Borne: Mangalore, Karnataka, India**



Mambillikalathil Govind Kumar Menon, FRS, was a physicist and science policy maker of India. MGK Menon was both a brilliant high energy particle physicist and an institution builder of Indian science. Menon was distinguished for investigations in the field of cosmic ray studies and in particular on the high-energy inter-actions of elementary particles . His work, at the University of Bristol with Nobel laureate Cecil Powell and others, on subatomic particle decay was a key experimental finding underpinning the discovery of “parity nonconservation” in such processes – for which Lee and Yang received the Nobel prize in 1957.

Menon joined the Tata Institute of Fundamental Research (TIFR) in Mumbai in 1955 at the invitation of Homi Bhabha, where he went on to establish one of the world’s leading groups on the study of cosmic rays near the geomagnetic equator from high-altitude balloon flights. Later, these stratospheric balloons would carry infrared, X-ray and gamma-ray payloads, thus paving the way, decades later, for Indian scientists building the space-borne AstroSat. His cosmic ray research also spawned gamma-ray facilities at Udhagamandalam and Pachmarhi, and later at Mount Abu and the High Altitude Gamma Ray Telescope (HAGAR) in Ladakh.

## *Amazing Physics*

His directorship of the Tata Institute of Fundamental Research (TIFR) in Mumbai, following the untimely demise of its founder HJ Bhabha, was critical in broadening the research undertaken by this world-class institution into areas of direct national impact.

The many positions he held include membership of the Planning Commission (1982-89), chairman of the Indian Space Research Organization (1972), Scientific Advisor to the Prime Minister (1986-89), presidentships of the national science academies, Minister of State for Science and Technology and Education (1989-90) and many other positions.

M.G.K.Menon received Padma Shri in 1961, Padma Bhushan in 1968, and Padma Vibhushan in 1985. The asteroid 7564 has been named Gokumenon in his honour.

## **19. Raja Ramanna (1925-2004)**

**Born: Tumkur, Karnataka, India**



Raja Ramanna was an Indian physicist who is best known for his role in India's nuclear program during its early stages. He made important contributions, both theoretical and experimental, in various areas of nuclear physics. Raja Ramanna was a multifaceted personality – an eminent nuclear physicist, a highly accomplished technologist, an able administrator, an inspiring leader, a gifted musician, and a scholar of Sanskrit literature and philosophy.

After completing his intermediate studies at St Joseph's, Bangalore Ramanna joined the Madras Christian College in Tambaram. He did very well in his intermediate examination. He was among the six students who were selected for BSc (Honours) course majoring in physics. After obtaining his BSc (Honours) degree in physics from Madras Christian College, he went to England to work for his doctoral in the field of nuclear physics at the King's College, London, as Tata Scholar.

*Amazing Physics*

His PhD work at King's College, London, involved the development of a new kind of ion chamber, which could measure not only the energy of a nuclear particle, but also its angle, with respect to the direction of the chamber's electric field. He obtained his PhD degree in 1948. Ramanna then joined the TIFR 1949.

He made significant contributions in the field of neutron thermalisation and reactor design. India's first nuclear reactor, Apsara, was designed under his guidance. He also played a leadership role in other important nuclear programs such as the Dhruva reactor, IGCAR, the Kolkata Cyclotron Centre and the CAT at Indore, which has been renamed as the Raja Ramanna Centre for Advanced Technology in his honour. Dr. Ramanna initiated and led the basic research in nuclear fission, using the neutron beams from the Apsara reactor in 1956. Pioneering research work was done on prompt neutrons and gamma rays, also on occasionally emitted alpha particles in fission, under Dr. Ramanna's supervision.

He was the Director of the Bhabha Atomic Research Centre (1972-78 and 1981-83). He was Scientific Advisor to the Minister of Defence; Director-General, DRDO and Secretary for Defence Research, Government of India (1978-81). He was Chairman of the Atomic Energy Commission (1984-87). He was first Director of the National Institute of Advanced Studies, Bangalore established by J. R. D. Tata.

## **20. Yash Pal (1926 - 2017)**

**Born : Jhang, Punjab Province, British India, now in Pakistan.**



Yash Pal was an Indian scientist and science communicator of excellence.

Yashpal was born at Jhang (now in Pakistan). He spent his early childhood in Quetta (Balochistan). He went to school in Quetta, Jabalpur, Lyllapur and studied BSc in Punjab University, Lahore. After post-graduation from Delhi University, he went to the Massachusetts Institute of Technology (MIT) for doctoral studies in Physics. He obtained the PhD degree in Physics from the Massachusetts Institute of Technology in 1958.

Yashpal began his scientific career at the Tata Institute of Fundamental Research (TIFR), Mumbai which was the fountainhead of space, atomic energy and electronics development. Yash Pal spent almost 35 years doing research in TIFR, where his main areas of research were cosmic rays and high-energy physics. As space technology began to grow in the 1970s, he was asked to head a special project SITE—Satellite Instructional Television Experiment

In 1972, the Government of India set up its Department of Space and embarked on an independent space programme. Yash Pal took charge as the first Director of the newly set up Space Applications Centre, Ahmedabad, in 1973. At the same time, he continued to be on the faculty of TIFR.

He was appointed chairman, University Grants Commission (UGC) and served in that capacity from 1986 to 1991. During his tenure as UGC chairman, he advocated the setting up of Inter-University Centres funded by the UGC, on the model of the Nuclear Science Centre (now Inter-University Accelerator Centre), New Delhi. Institutions such as the Inter-University Centre for Astronomy and Astrophysics (IUCAA) emerged from this vision.

Recipient of the civilian awards Padma Bhushan and Padma Vibhushan for his outstanding contribution to science and space technology, Yash Pal served as Secretary to the Department of Science, and as Chancellor of Jawaharlal Nehru University in New Delhi.

## **21. N. S. Kapany (1926 - )**

**Born: Moga, Punjab, India**



Narinder Singh Kapany is an Indian-born American physicist known for his work in fibre optics. He is known as "Father of Fiber Optics". The 'term fibre optics' was coined by Kapany in 1956.

N.S.Kapany was born in Punjab, and studied at Agra University. He joined the Imperial College London in 1952 to work on a Ph.D. degree in optics, which he obtained in 1955.

At Imperial College, Kapany worked with Harold Hopkins on transmission through fibers, achieving good image transmission through a large bundle of optical fibers for the first time in 1953. Optical fibers had been tried for image transmission before, but Hopkins and Kapany's technique allowed much better image quality than could previously be achieved. This, combined with the almost-simultaneous development of optical cladding by Dutch scientist Bram van Heel, started the new field of fibre optics. Kapany coined the term 'fibre optics' in an article in Scientific American in 1960, wrote the first book about the new field, and was the new field's most prominent researcher, writer, and spokesperson.

Kapany's research and work have encompassed fibre-optics communications, lasers, bio-medical instrumentation, solar energy and pollution monitoring. He has over one hundred patents, and was a member of the National Inventors Council.

## **22. Piara Singh Gill (1911-2002)**

**Born: Hoshiarpur district, Punjab, India**

Piara Singh Gill was an Indian nuclear physicist who was also a pioneer in cosmic ray studies.



Piara Singh Gill was born in the village of Chela in Hoshiarpur district of Punjab. He attended Khalsa High School in Mahilpur (1928) and left for America in 1929.

He earned a merit scholarship at the University of Southern California and completed his Bachelor's and Master's degrees (1936) from there. He joined the doctorate program in October

1936 at the University of Chicago. His supervisor was Professor Arthur Compton who won the Nobel Prize. The Compton group was interested in the latitude effect of cosmic rays. Gill took several sea voyages from Vancouver (Canada) to Tasmania (Australia) to collect his data (1938-39). He was awarded the Ph.D. in Physics in the year 1940.

Gill presented a paper on the 'Size-frequency distribution of cosmic ray bursts' at the International Symposium on Cosmic Rays (June 1939). It was the first experiment showing the clues about the spin of the pi-meson that was predicted by the Japanese Physicist Yukawa.

Gill returned to India in 1945 and started his work at Christian College Lahore. Gill began his research laboratory to continue the work he had started in Chicago. He used a Royal Air Force 'Mosquito' plane and flew up to heights of 33,000 ft. He found mesons were produced beyond 20,000 ft.

Piara Singh Gill was a good friend and close colleague of Homi J. Bhabha, who offered him the research fellow Professorship at Tata Institute of Fundamental Research in 1947. But after a brief spell, he left TIFR and joined AMU, and was in charge of the Department of Physics, at A.M.U. In 1951, Gill set up a high altitude laboratory at Gulmarg. His students studied the variations of cosmic rays and extensive air showers at high altitudes. Gill impressed Prime Minister Nehru with his scientific breakthroughs and acumen. Nehru offered him the post of Officer-on-Special Duty (OSD) with the Atomic Energy Commission in New Delhi and he also asked him to become the first Director of Central Scientific Instruments Organization (CSIO) of India. Professor Piara Singh Gill was a key advisor and planner to Nehru on India's nuclear weapons strategy in the 1950-60s.

## **23. Satish Dhawan (1920 – 2002)**

**Born: Srinagar, Kashmir, India**



Satish Dhawan was an Indian scientist and aerospace engineer, widely regarded as the father of experimental fluid dynamics research in India. Dhawan was one of the most eminent researchers in the field of turbulence and boundary layers.

Satish Dhawan graduated from the University of Punjab with BA in (Mathematics and Physics), MA in (English Literature) and a BE in (Mechanical Engineering). In the year 1947, Dhawan completed his MS in (Aeronautical Engineering) from the University of Minnesota and

moved to the California Institute of Technology, where he was awarded the Aeronautical Engineer's Degree in 1949. He completed his PhD in Aeronautics and Mathematics from Caltech in 1951.

Satish Dhawan is known for leading the successful and indigenous development of the Indian space programme. He succeeded M. G. K. Menon, as the third chairman of the Indian Space Research Organisation (ISRO) in 1972. In the decade following his appointment he directed the Indian space programme through a period of extraordinary growth and spectacular achievement. He was also the Chairman of the Space Commission and Secretary to the Government of India in the Department of Space.

Even while he was the head of the Indian space programme, he devoted substantial efforts towards boundary layer research. His most important contributions are presented in the seminal book *Boundary Layer Theory* by Hermann Schlichting.

He was a popular professor at the Indian Institute of Science, (IISc) in Bangalore. He is credited for setting up the first supersonic wind tunnel in India at IISc. He also pioneered research on relaminarization of separated boundary layer flows, three-dimensional boundary layers and trisomic flows.

## **24. Anna Mani ( 1918 – 2001)**

**Born: Peerumedu, Kerala, India**



Anna Mani was an Indian physicist and meteorologist. She made several contributions to the field of meteorological instrumentation, conducted research and published numerous papers on solar radiation, ozone and wind energy measurements.

In 1940, a year after finishing her honours degree in Physics and Chemistry from the Presidency College in Madras, Anna Mani obtained a scholarship to do research in physics at the Indian Institute of Science and was accepted in C.V. Raman's laboratory as a graduate student. In Raman's laboratory, Anna Mani worked on the spectroscopy of diamonds and rubies.

Between 1942 and 1945, she published five papers single authored on the luminescence of diamonds and rubies. In August 1945 she submitted her Ph.D. dissertation to Madras University but she was declined a doctorate as she did not possess a master's degree. Utilising the government scholarship for an internship in England, Mani went to the Imperial College in London to pursue physics in 1945. However, she ended up specializing in meteorological instrumentation as it was the only internship available. When Mani returned to independent India in 1948, she joined the Indian Meteorological Department at Pune.

She undertook the development of an apparatus to measure ozone – ozonesonde. This enabled India to collect reliable data on the ozone layer. Thanks to Mani's singular contribution, she was made a member of the International Ozone Commission.

In 1976, Anna Mani retired as deputy director general of the Indian Meteorological Department and returned to the Raman Research Institute as a visiting professor for three years. Later she set up a millimetre-wave telescope at Nandi Hills, Bangalore.

A visionary, Anna Mani foresaw that alternative sources of energy would have a big role to play in India's future development. She organised round-the-year wind speed measurement from over 700 sites using state-of-art equipment. In the 1980s, Anna Mani published two books; the *Handbook of Solar Radiation Data for India* and *Solar Radiation over India*. Both these books became standard references for those engaged in the design and deployment of solar thermal systems in India.

## **25. A.K. Raychaudhuri (1923 - 2005)**

**Born : Barisal, Bengal (now in Bangladesh)**

**Amal Kumar Raychaudhuri** was an Indian physicist, known for his research in general relativity and cosmology. His most significant contribution is the famous Raychaudhuri equation, which demonstrates that singularities arise inevitably in general relativity, and is a key ingredient in the proofs of the Penrose–Hawking singularity theorems



A.K.Raychaudhuri did his graduation from Presidency College in 1942 followed by master's degree from Calcutta University in 1944. Right after this he joined as a research fellow in

the Indian Association for the Cultivation of Science (IACS) to work in X-ray crystallography and then Ashutosh college, Calcutta as a lecturer in 1949. Later in 1952 he again joined IACS as a research assistant. It was around that time he formulated the famous 'Raychaudhuri equation'.

Raychaudhuri published his famous equation in the year 1954 and the first mention of '*Raychaudhuri equation*' appeared in a research paper published in 1965 by George F. R. Ellis and Stephen Hawking. In fact, this equation is the foundation of the famous Penrose-Hawking singularity theory in cosmology.

The area in general relativity and cosmology that AKR chose to work on, related to the formation of large scale structure in the universe. This field had been explored by Eddington and Lemaitre in the 1930s. AKR's early work also included clarifying the physical nature of the classical Schwarzschild solution.

AKR's main impact, however, was in the field of cosmological models. The attempt to understand the large scale properties of the universe with the help of mathematical models really took off in 1917 with Einstein's attempts to describe the universe (believed to be static) as a 'solution' of his field equations. The Raychaudhuri equation paved the way for later research into the singularity problem.

AKR wrote a monograph on Theoretical Cosmology which is now a well known introduction to the subject for those who wish to enter it for research.

AKR was well recognized by his peers internationally in the field of general relativity and gravitation. He was elected member of the International Committee on General Relativity and Gravitation for the period 1974-83.

## **26. Govind Swarup (1929- 2020)**

**Born: Thakurdwara in the Moradabad district, Uttar Pradesh, India**

**Govind Swarup** is the pioneer of radio astronomy in India. He is known not only for his many important research contributions in several areas of astronomy and astrophysics, but also for his outstanding achievements in building ingenious, innovative and powerful observational facilities for front-line research in radio astronomy. Over a period of 7 decades, he built two of the world's largest radio telescopes and nurtured a community of Indian radio astronomers. He was the key scientist behind concept, design and installation of the Ooty Radio Telescope (India) and the Giant Metrewave Radio Telescope (GMRT) near Pune. Under his leadership, a strong group in radio astrophysics emerged at Tata Institute of Fundamental Research (TIFR) that is comparable to the best in the world.



Govind Swarup obtained his MSc degree from Allahabad University in 1950 and then joined the newly formed National Physical Laboratory (NPL). He began working in the area of paramagnetic resonance under the direction of the eminent physicist K. S. Krishnan. In 1956, Swarup joined the Fort Davis Radio Astronomy station of Harvard Observatory, located in Texas, to continue his studies of the Sun. Swarup discovered a new type of burst from the Sun - a Type U burst - during his stay at Harvard. He stayed on to do a PhD in the USA and chose Stanford Stanford PhD program which placed a greater emphasis on the newly emerging field of electronics.

Swarup returned to India in 1963 and joined TIFR. By 1965, he had used the dishes from the Pott's Hill Telescope to set up a solar telescope at Kalyan, near Mumbai.

Govind Swarup then led the effort to build a large radio telescope in Ooty. This massive telescope, a 500 m long and 30 wide parabolic cyclinder had its rotation axis parallel to the earth's rotation axis and could follow a radio source from rise to set. By 1970, the Ooty Radio Telescope (ORT) was complete.

By the early 1980s new technological developments made it possible to envision a telescope even bigger than the ORT. Swarup then dreamt up his biggest project yet, the Giant Meterwave Radio Telescope. The goal of this massive new telescope was to discover primordial hydrogen clouds in the very distant Universe. The telescope was ready by the year 2000, and has since then been open to the international astronomy community.

## **27. Roddam Narasimha (1933 - )**

**Born : Bengaluru, Karnataka, India**

**Roddam Narasimha** is well known aerospace scientist and fluid dynamicist. He was a Professor of Aerospace Engineering at the Indian Institute of Science (IISc), Director of National Aerospace Laboratories (NAL) and the Chairman of Engineering Mechanics Unit at Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bangalore. He is now an Honorary Professor at JNCASR and concurrently holds the Pratt & Whitney Chair in Science and Engineering at the University of Hyderabad.



Roddam Narasimha obtained his BE from Mysore University in 1953 and his ME from Indian Institute of Science, Bangalore in 1955. He worked with Prof. Satish Dhawan during his time at IISc. He then worked with Prof. Hans Liepmann at the California Institute of Technology (Caltech), United States to obtain his PhD degree in 1961

Roddam Narasimha's major interests have been in fluid dynamical problems associated with aerospace and atmospheric sciences, two fields in which turbulent fluid flow plays an important role.

In aerospace problems, his recent work has focused on multiple transitions between laminar and turbulent flow on swept wings characteristic of modern transport aircraft, and on the design of optimal wing planforms for minimum induced drag on propeller-driven aircraft. The new wings can enhance the inherently greener characteristics of the propeller compared to turbojet/fan engines. International patents have been filed on the novel wing planforms.

In the atmosphere, turbulent flow in the tropics has a strongly convective character, and the laws governing it at low winds are of great interest in monsoon predictions. New scaling laws for such tropical boundary layers have been proposed, and these have improved prediction skills in atmospheric circulation models. Cloud flows are also a major area of interest for Narasimha. Recent laboratory experiments have successfully simulated the form, evolution and entrainment characteristics of natural clouds. These developments promise to provide deeper insights into the important problem of cumulus cloud dynamics.

Narasimha has been awarded the Padma Vibushan in 2013.

## 28. Jayant Narlikar (1938- )

**Born : Kolhapur, Maharashtra, India**



**Jayant Vishnu Narlikar** is an Indian astrophysicist. He is a proponent of “steady state theory” of the universe. Along with Sir Fred Hoyle, he developed the Hoyle-Narlikar Theory.

Narlikar received his early education at the Banaras Hindu University where his father Vishnu Vasudeva Narlikar was Professor and Head of the Mathematics Department. He got his B.Sc. degree from BHU in 1957. Thereafter he went to Cambridge for higher studies, becoming a Wrangler and Tyson Medallist in the Mathematical Tripos. He distinguished himself at Cambridge with the Smith’s Prize in 1962 and the Adams Prize in 1967. He later stayed on at Cambridge till 1972, as Fellow of King’s College (1963-72) and Founder Staff Member of the Institute of Theoretical Astronomy (1966-72).

Narlikar returned to India to join the Tata Institute of Fundamental Research (1972-1989) where under his charge the Theoretical Astrophysics Group expanded and acquired international standing. In 1988 he set up the Inter-University Centre for Astronomy and Astrophysics (IUCAA) as its Founder Director. He held the Directorship of IUCAA until his retirement in 2003. He is now Emeritus Professor at IUCAA.

Narlikar is internationally known for his work in astrophysics and cosmology, and for championing models alternative to the popularly believed big bang model. His work has been on the frontiers of gravity and Mach’s Principle, quantum cosmology and action at a distance physics. His research work in Cambridge was on the development of the steady state theory as a viable theory of the universe and on action at a distance approach to electrodynamics and gravity. His work with Chitre in 1978 on the explanation of apparent superluminal motions in quasars through gravitational lensing, was ahead of time. In 1977, Narlikar initiated a long-term programme of conformal quantization of gravity which led him to the avoidance of space time singularity in quantum cosmology. In 1993, he joined with Hoyle and Geoffrey Burbidge in proposing an alternative to big bang cosmology, known as the quasi-steady state cosmology.

Apart from his scientific research, Narlikar is well known as a science communicator through his books, articles, and radio/TV programmes. He is also known for his science fiction stories.

Narlikar was decorated with Padmabhushan in 1965, at the young age of 26. In 2004 he was awarded Padmavibhushan. In 2011, the Government of the State of Maharashtra honoured him with the State's highest civilian award of Maharashtra Bhushan.

## **29. B.V.Sreekanth (1925- )**

**Born: Nanjagund, Karnataka, India**

**Badanaval Venkatasubba Sreekanth** is an Indian high-energy astrophysicist, known for his studies in the fields of cosmic rays, elementary particles, and high-energy X-ray astronomy.



B.V. Sreekanth conducted his research at TIFR for 39 years, and before his retirement he served as the director of the institute from 1975. At TIFR, he initiated many research streams in cosmic ray physics and astrophysics. One of his early assignments at TIFR was the study of cosmic-ray-produced muons detected deep underground. Sreekanth conducted experiments at Kolar Gold Mines in Karnataka, for the detection of the elementary particles at 2760 m deep. Though his experiments failed to find cosmic ray produced muons, he continued his search, which resulted in the detection of cosmic ray produced neutrinos, reportedly the first detection of the subatomic particles at such depth.

In 1954 Sreekanth's worked at the Massachusetts Institute of Technology with Italian experimental physicist, Bruno Rossi on cloud chambers and K-mesons. He visited Brookhaven National Laboratory and conducted experiments on K-meson decay which resulted in the publication of three scientific papers, jointly written with Herbert S. Bridge and others. Once back at TIFR, he

started a new series of balloon-borne experiments for studying cosmic X-ray sources above 20 keV which helped in the future development of X-ray detectors for X-ray astronomy missions. Three X-ray instruments developed by his group were carried on the Astrosat, the first multiwavelength astronomy observatory, which was launched in October 2015.

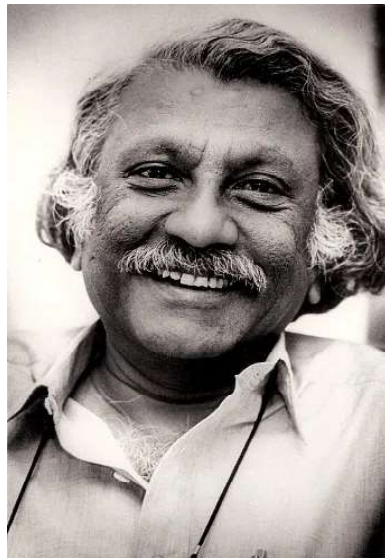
He assisted Homi Bhabha in the installation of two cloud chambers, Rani and Maharani at the cosmic ray laboratory in Ooty in 1954. Later, a larger cloud chamber, the largest one in India till then, and an air shower array were also set up there, with his assistance. Sreekanttan and his group also designed a total absorption spectrometer and an air Cherenkov counter.

The Government of India awarded him the Padma Bhushan, India's third highest civilian honour, in 1988.

## **30. V. Radhakrishnan (1929 - 2011 )**

**Born: Tondiarpet, Madras, Tamilnadu, India**

**Venkatraman Radhakrishnan**, son of Nobel laureate Sir C V Raman, was a globally renowned space scientist . He was also known for his design and fabrication of ultralight aircraft and sailboats. Radhakrishnan was one of the most respected radio astronomers in the world during his time, in that he was associated in one capacity or other with the world's biggest radio telescopes. His observations and theoretical insights helped the community in unraveling many mysteries surrounding pulsars, interstellar clouds, galaxy structures and various other celestial bodies.



Prof. Radhakrishnan started his career as Research scholar at Indian Institute of Science, Bangalore in 1951. He joined Chalmers University of Technology as Research Assistant

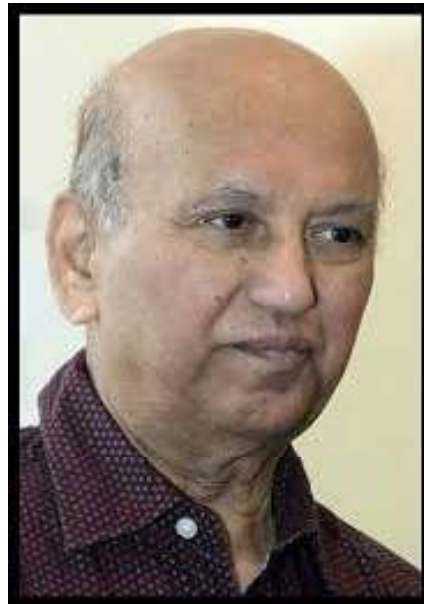
during 1955-58. He was Senior Research Fellow during 1959-64 at California Institute of Technology, USA. Radhakrishnan next moved to the CSIRO Division of Radio physics in Australia in 1965 as Principal Research Scientist and was there up to 1971. He was with Meudon Observatory, France during 1971-72.

During his tenure as the director of the Raman Research Institute between 1972–1994 he built up an international reputation for work in the areas of pulsar astronomy, and other areas of frontline research in Astronomy. Radhakrishnan with his students and colleagues, worked on many aspects of pulsars and the interstellar medium such as 'A survey of lowfrequency recombination lines', the proposal of 'recycled pulsars', and a model for the 'X-ray nebula around the Vela pulsar'. He has contributed in the fields of planetary radiation, interstellar hydrogen, radio source polarization and observations and interpretations of pulsar radiation.

The University of Amsterdam conferred the most prestigious Doctor Honoris Causa degree on Prof. Radhakrishnan in 1996. He was a member of the Royal Swedish Academy of Sciences.

## **31. U R Rao (1932 – 2017)**

**Born : Adamaru(South Canara), Karnataka, India**



**Udupi Ramachandra Rao** was a space scientist and chairman of the Indian Space Research Organisation(ISRO). He was is an internationally renowned scientist who had made original contributions to the development of space technology in India and its extensive application to communications and remote sensing of natural resources.

U.R Rao completed his M.Sc in Physics from BHU in 1953, and completed his Ph.D at Physical Research Laboratory, Ahmedabad under the guidance of Dr. Vikram Sarabhai in 1960.

The cosmic ray studies he started with Vikram Sarabhai were continued at MIT in the USA. In association with the Jet Propulsion Laboratory group, he was the first to establish the continuous nature of the solar wind and its effect on geomagnetism using Mariner 2 observations. Rao's experiments on a number of Pioneer and Explorer spacecraft led to a complete understanding of the solar cosmic ray phenomena and the electromagnetic state of the interplanetary space.

Convinced of the imperative need to use space technology for rapid development, Rao undertook the responsibility for the establishment of satellite technology in India in 1972. Under his guidance, beginning with the first Indian satellite "Aryabhata" in 1975, over 18 satellites were designed, fabricated and launched for providing communication, remote sensing and meteorological services.

Prof Rao published over 350 scientific and technical papers covering cosmic rays, interplanetary physics, high energy astronomy, space applications and satellite and rocket technology and authored many books

Rao was awarded the Padma Bhushan by the Government of India in 1976, and Padma Vibhushan in 2017. He was inducted into the Satellite Hall of Fame, Washington, on 19 March 2013 at a ceremony organised by the Society of Satellite Professionals International.

## **32. R. Vijayaraghavan (1931- )**

**Born: Tamilnadu, India**

**Ramanuja Vijayaraghavan** is an Indian physicist specializing in condensed matter physics. Vijayaraghavan has made significant contributions in the study of metals and alloys by the nuclear magnetic resonance technique.



After graduating from the Annamalai University in 1951, Vijayaraghavan joined the Tata Institute of Fundamental Research (TIFR) at Bombay as a Research Student, eventually rising to

the position of Distinguished Professor and Dean (Physics Faculty). In the 1950s, he constructed a crossed circle wide line NMR spectrometer which could detect deuterium and oxygen-17 isotopes in their natural abundance. Using oxygen-17 as a probe, he demonstrated chemical shifts in organic liquids due to electronic bonding. He subsequently developed an interdisciplinary group which used NMR and susceptibility measurements in metals to show that susceptibility and the hyperfine field at the nucleus were related and could be modified by alloying. The oscillatory nature of the conduction electron polarisation was established in rare earth alloys. The findings from experiments performed in bulk samples of transition metals, rare earths, Heusler alloys and spin glass were related to results obtained from microscopic techniques such as NMR, Mossbauer and neutron diffraction. He and his collaborators, are credited with the discovery of superconductivity in borocarbides with magnetic elements and new valence fluctuating materials, heavy fermions, rare earth magnetism phenomena and highly correlated electron systems. His group also made early contributions to the detection of tumors by magnetic resonance.

Vijayaraghavan was deputed twice by the International Atomic Energy Agency (IAEA), Vienna, Austria, as an Expert to set up the Magnetic Resonance Laboratory at the Atomic Energy Centre, Yogyakarta, Indonesia.

As a tribute to his contribution to physics, two felicitation volumes were published in 1991 on the occasion of his 60th birthday: *Frontiers in solid state series, Superconductivity (Vol.1), and Magnetism (Vol. 2)*, by World Scientific Publishing, in Singapore. Vijayaraghavan was conferred the prestigious Shanti Swarup Bhatnagar Award in 1976, and received the UGC Raman award in Physical Sciences in 1983.

### **33. P. K. Kaw (1948 – 2017)**

**Born: Srinagar, Kashmir, India**

**Predhiman Krishan Kaw** was an Indian plasma physicist. He was the founding director of the Institute for Plasma Research and served the institute as the the director from 1986 to 2012.

After obtaining a PhD at age 18 from the Indian Institute of Technology, Delhi, P.K.Kaw spent time as a researcher at the Physical Research Laboratory in Ahmedabad, India, and the Princeton Plasma Physics Laboratory, New Jersey, US. In 1982 he returned to India to spearhead the establishment of a national magnetic fusion program, founding the Institute for Plasma Research.



Recognized internationally for significant contributions to many areas of plasma physics, Professor Kaw has authored over 380 research publications in scientific journals. Kaw was behind the construction of the country's first indigenously-designed machine for controlling thermonuclear fusion, *Aditya tokamak*.

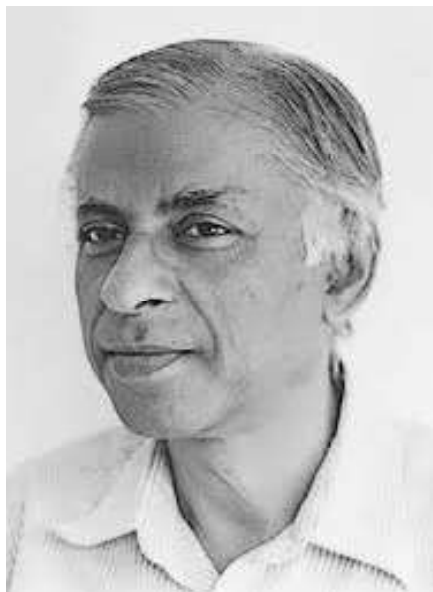
He was awarded the prestigious Padma Shri award in 1985 and Shanti Swarup Bhatnagar Award in 1986. On December 28, 2016 he was awarded the Subrahmanyan Chandrasekhar Prize of Plasma Physics by the Association of Asia-Pacific Physical Societies (AAPPS) for his seminal contributions in the areas of laser-plasma interactions, strongly coupled dusty plasmas, and turbulence, nonlinear effect in magnetic fusion devices. He is also a recipient of the 2008 TWAS Prize.

## **34. N. Mukunda (1939- )**

**Born : New Delhi, India**

Narasimhaiengar Mukunda is an Indian theoretical physicist, who worked at TIFR and Indian Institute of Science.

N. Mukunda obtained his BSc (Hons) in Mathematics from Delhi University (1958), and then joined the physics section of the Atomic Energy Establishment Trombay Training School. After two years in the Theoretical Physics Group of the Tata Institute of Fundamental Research (TIFR), Mumbai, he went to the University of Rochester, USA, and completed his PhD (1964) under the guidance of ECG Sudarshan. Mukunda's thesis dealt with Hamiltonian mechanics, symmetry groups and elementary particles. He studied group theory at Princeton University with Valentine Bargmann, including topological groups and Lie theory. Following Research Associateships at Princeton and Syracuse Universities, he returned to TIFR (1967) as a member of the Theoretical Physics Group. In 1972 he moved to the newly created Centre for Theoretical Studies at the Indian Institute of Science, Bangalore, from where he retired in 2001.



Mukunda has worked in several areas of mathematical and theoretical physics such as group structure and representations for physical problems, in particular, the Lorenz and Poincare groups and certain compact Lie groups; infinite component relativistic wave equations; theory of constrained classical dynamical systems; and applications to relativistic point particles with internal structure. In quantum mechanics his areas of work are: coherent states and their generalizations; new approaches to geometric phases; theory of Wigner distributions; classical optics including polarization, partial coherence, beam characterization and propagation problems. He has published about 180 research papers and co-authored four books.

Professor Mukunda received the SS Bhatnagar Prize (1980). He received the Meghnad Saha Award of the UGC (1985), the Jawaharlal Nehru Birth Centenary Lecture Award of INSA (1992), and Sir M Visvesvaraya State Award from Government of Karnataka (2003). He is a Fellow of the Indian Academy of Sciences, Bangalore, the National Academy of Sciences, India, Allahabad, and the Academy of Sciences for the Developing World, Trieste.

## **35. A. P. Balachandran (1938- )**

**Born : Salem, Tamil Nadu, India**

Aiyalam Parameswaran Balachandran is an Indian theoretical physicist well known for his extensive contributions to the role of classical topology in quantum physics.



Balachandran completed his first two college years in Guruvayurappan College, Kozhikode, Kerala, specialising in physics, chemistry and mathematics and passing the 'Intermediate Examination' with all-State distinction in 1953. He joined BSc (Hons) in Physics in the Madras Christian College, Chennai. Balachandran passed out of MCC in 1958. Balachandran got his PhD under guidance of Prof. Alladi Ramakrishnan from Madras University in 1962. Then he joined Theoretisch Physics, University at Wien as a postdoctoral fellow under Professor Walter Thirring, subsequently also at the Enrico Fermi Institute as a postdoc. In 1964, he joined the Syracuse University faculty.

A.P. Balachandran is currently an emeritus professor in the Department of Physics, Syracuse University, where he was previously the Joel Dorman Steele Professor of Physics between 1999 and 2012. Balachandran's key scientific works include the revival of the Skyrme model which successfully describes baryons as topological solitons of meson fields and mathematical concepts such as homotopy groups and fibre bundles to problems in quantum physics.

In 1990, Syracuse University honored him with a Chancellor's Citation for Exceptional Academic Achievement. He has been a fellow of the American Physical Society since 1988.

## **36. P. I. John (1941- )**

**Born: Kottayam, Kerala, India**

**Pucadyil Ittoop John** is an Indian plasma physicist. He occupies the Meghnad Saha Chair in Plasma Science and Technology at the Institute for Plasma Research, Ahmedabad.

After completing his Ph.D. at Aligarh Muslim University, John joined the Physical Research Laboratory, where he established an experimental plasma physics program in 1972. He was the Chairman of the Plasma Physics Group at PRL until 1982.



P.I. John was one of the leading members of the group who initiated India's Fusion Research Program, which developed into the Institute for Plasma Research (IPR). along with P.K.Kaw, he supervised, and was instrumental in the erection and commissioning of the first indigenously built Indian Tokamak, Aditya, and was also the project leader of its pulsed power systems. He was also chairman of the Board of Research in Fusion Science & Technology (BRFST), which is involved with the National Fusion Program in India.

In the early 1990s, he started a plasma processing program at the Institute for Plasma Research (IPR) to facilitate plasma based industrial applications, which grew into the Facilitation Centre for Industrial Plasma Technologies (FCIPT) at Gandhinagar, Gujarat, India. He was the head of FCIPT for many years, and is still a member of its governing Council.

In 2002-03, John served as Head of the Physics Section of the International Atomic Energy Agency. He was also part of the Indian Task Force for ITER negotiations, before India joined the ITER as a full member.

John has close to 100 publications in international journals and holds 12 patents for plasma devices and plasma-aided manufacturing processes. His book "***Plasma Sciences and the Creation of Wealth***", published by Tata McGraw-Hill in 2005 addresses a broad audience on the value addition through plasma-based technologies. A translation of this book into the Chinese language has been brought out. His second book "***Plasma Processes for Energy and Environment***" was published by Lambert Publishers in November 2017. In 2010, Professor John received the prestigious Padma Shri award from the Government of India.

## 37. Abhay Ashtekar (1949- )

**Birthplace: Kolhapur, India**



**Abhay Ashtekar** is a theoretical physicist specializing in general relativity, cosmology and quantum gravity. He is best known for initiating the Loop Quantum Gravity program, for analyzing the very early universe, and for his contributions to the study of the asymptotic structure of space-time and gravitational waves in full non-linear general relativity.

Ashtekar received his undergraduate education in India and his PhD from the University of Chicago (1978). He was Professeur at University of Paris VI and held the Erastus Franklin Holden Chair at Syracuse University before assuming the Eberly Chair in Physics at Penn State university. At Penn State, he also serves as Director of the Institute for Gravitation and the Cosmos.

Ashtekar has authored over 270 scientific papers and written or co-edited nine scientific books on general relativity, cosmology and quantum gravity. His research has advanced the understanding of the asymptotic structure of space-time, gravitational waves in full nonlinear general relativity, atomic structure of space-time geometry on the Planck scale, and the quantum nature of black holes and Big Bang. His reformulation of general relativity as a gauge theory has led to loop quantum gravity, an approach to the unification of general relativity and quantum physics that is now being pursued in dozens of research groups worldwide.

Ashtekar was awarded the senior Forschungspreis by the Alexander von Humboldt Foundation and has held the Krammers Visiting Chair in Theoretical Physics at the University of Utrecht, Netherlands. He held Senior Visiting Fellowship of the British Science and Engineering Research Council, and the Sir C. V. Raman Chair of the Indian Academy of Science. He was awarded Doctor Rerum Naturalium Honoris Causa by the Friedrich-Schiller Universitaet, Jena, Germany in 2005 and by the Universite' de Aix-Marseille II, France in 2010. He is a past president of the International Society for General Relativity and Gravitation, and a past chair of what is now the Division of Gravitational Physics of the American Physical Society. He is an honorary Fellow of the Indian Academy of Science, and a member of the US National Academy.

## **38. G. S. Agarwal (1946- )**

**Born: Bareilly, Uttar Pradesh, India**



Girish S. Agarwal, is an Indian theoretical physicist working in the United States. He is currently at the Texas A & M University with affiliations to the Departments of Biological and Agricultural Engineering, Physics and Astronomy, and the Institute for Quantum Science and Engineering. Earlier he worked as Noble Foundation Chair and the Regents Professor at the Oklahoma State University. He is a recognized leader in the field of quantum optics and also has made major contributions to the fields of nonlinear optics, nanophotonics and plasmonics.

G. S. Agarwal specializes primarily in quantum optics and broadly in quantum physics. The theoretical work focuses on quantum effects in hybrid systems; quantum phase transitions and collective effects in cavities driven by squeezed light; Frohlich condensates; coupling of quantum emitters to meta materials; chiral quantum systems. The experimental effort based on super-resolution microscopy, quantum sensing and speckle imaging is focused towards bio-photonics applications.

Girish Saran Agarwal earned his MSc degree from Banaras Hindu University and his PhD from University of Rochester, USA in 1969 under the supervision of Emil Wolf. He did his postdoctoral research with Herman Haken at University Stuttgart, Germany. He began his career as a Visiting Fellow at the Tata Institute of Fundamental Research (TIFR), Mumbai, and later as Professor at the Institute of Science, Mumbai (1975-77). He continued his career as Professor of Physics at the University of Hyderabad. He then moved to Physical Research Laboratory, Ahmedabad as Director. He also occupied the chair of INSA-Albert Einstein Centenary Research Professor (2001-05). He served as Noble Foundation Chair and Regents Professor at The Oklahoma State University ( 2004- 2017). He is currently with the Texas A & M University where he leads a

very active group in quantum optics, biophotonics and imaging.

G. S. Agarwal has made extensive contributions to many areas of quantum optics-coherence, superfluorescence, bistability, resonance fluorescence and cavity QED. Has been instrumental in starting quantum optical work in several areas like cooperative resonance fluorescence, applications of master equation techniques, optical resonance and nonlinear optical phenomena in partially coherent fields, quantum electrodynamic phenomena at surfaces, quantum state engineering, control of decoherence, quantum imaging and microscopy. In 2013 he published the textbook "Quantum Optics", covering a wide range of recent developments in the field, which has been well received by the community

Girish S. Agarwal is a Fellow of the Royal Society UK. He was awarded Max Born Award (1988), Humboldt Research Award (1997), and The Physics Prize (1994).

## **39. T.V.Ramakrishnan (1941- )**

**Born: Chennai, Tamilnadu, India**



T.V.Ramakrishnan is Emeritus Professor of Physics, DAE Homi Bhabha Professor Banaras Hindu University, Varanasi and Distinguished Associate, Centre for Condensed Matter Theory at Department of Physics, Indian Institute of Science, Bangalore.

T.V.Ramakrishnan did both B.Sc.and M.Sc in Physics at Banaras Hindu University, Varanasi. He then completed his Ph.D. from Columbia University in 1966. He started his professional career as lecturer in the Indian Institute of Technology, Kanpur. He shifted to the Indian Institute of Science, Bangalore in 1986 where he continued till 2003.

T.V. Ramakrishnan has made crucial contributions to our understanding of condensed many body systems. His pioneering work started two major areas of activity. These are: the liquid-solid transition as well as related phenomena in dense classical systems, and the onset of electron localization in disordered systems. In a third area, namely mixed valence in rare-earth metals, his work on the inverse orbital degeneracy expansion has had a major effect on the field.

His awards and honours include the Shanti Swarup Bhatnagar Award for Physical Sciences (1982), the Third World Academy of Sciences Award in Physics (1990), the Padma Sri (2001) and the 2005 Trieste Science Prize. He is a Fellow of the Royal Society.

## **40. Ashoke Sen (1956 - )**

**Born: Kolkata, Bengal, India**



Ashoke Sen is Professor at the Harish-Chandra Research Institute, Allahabad. He received his PhD from the SUNY at Stony Brook in 1982.

He has made pioneering contributions to the development of string theory. Dr. Sen's work on 'strong-weak coupling duality', which is useful for doing calculations in theoretical physics, won him the first ever 'Fundamental Physics Prize'.

Dr. Sen also studied unstable D-branes--a class of strings with endpoints that satisfy certain mathematical conditions, and he developed the famous 'Sen conjecture'. His work on rolling tachyons--a hypothetical particle that always moves faster than light--is seminal in the field of string theory with applications in string cosmology--a field that applies equations from string theory to solve the questions of early Universe cosmology.

In recognition of his contributions to the field of physics, in 1998 Sen was elected a Fellow of the Royal Society of London. He is also awarded the Padma Shri by the Indian government. He has been awarded the ICTP prize in 1989, S S Bhatnagar Award in 1994 and the Third World Academy prize in 1997.

## **41. Thanu Padmanabhan (1957- )**

**Birthplace: Thiruvananthapuram, Kerala, India**



Professor Thanu Padmanabhan is an internationally acclaimed Theoretical Physicist and Cosmologist whose research spans a wide variety of topics in Gravitation, Structure formation in the universe and Quantum Gravity. He has published more than 240 papers and reviews in international journals and nine books in these areas. Many of his contributions, especially those related to the analysis and modeling of dark energy in the universe and the thermodynamics of spacetime horizons, have made significant impact in the field.

Born in 1957, Padmanabhan took his B.Sc. and M.Sc. degrees in Physics from Kerala University and was a Gold medallist in both. Subsequently he joined TIFR, Mumbai where he did his Ph.D. in Physics. He held various positions at TIFR during 1980-1992 and also spent a year (in 1986-87) at the Institute of Astronomy, Cambridge for his postdoctoral research. He moved to the Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune in 1992 and became Dean, Core Academic Programmes of that Centre in 1997, which is the position he is currently holding. He has been a visiting faculty at several places abroad including Caltech, Princeton University and Institute of Astronomy, Cambridge.

Professor Padmanabhan has received numerous awards and distinctions in India and abroad for his contributions. The international distinctions received by him include the position of Sackler Distinguished Astronomer from the Institute of Astronomy, Cambridge, the Al-Khwarizmi International Award and the Miegunah Fellowship of the University of Melbourne. His research has won prizes from the Gravity Research Foundation, USA seven times in the past including the First Prize recently in 2008. He was honoured with a Padma Shri by the President of India in 2007.

## **42. Sriram Ramaswamy (1957- )**

Sriram Rajagopal Ramaswamy FRS is a Professor at the Indian Institute of Science, Bangalore.



Sriram Ramaswamy is a theoretician with broad interests in nonequilibrium, soft-matter and biological physics. His research helped found the field of Active Matter, which studies the collective behavior of objects, such as motile organisms, that convert local energy input into autonomous motion.

He is widely known for formulating the hydrodynamic equations governing the alignment, flow, mechanics and statistical properties of suspensions of self-propelled creatures, on scales from a cell to the ocean. Key predictions -- that macroscopically aligned flocks of swimming bacteria are impossible, and that the addition of swimmers to a fluid can make the viscosity arbitrarily small -- have been confirmed in recent experiments. His insight into nonliving imitations of self-propulsion has led to design principles for chemotactic colloids, the first experiments observing giant number fluctuations in flocks, and the creation of flocks with a tiny minority of motile constituents.

From 2012 to 2016 Sriram directed the TIFR Centre for Interdisciplinary Sciences in Hyderabad. Among the awards he has received for his research are the Shanti Swarup Bhatnagar Prize (2000) and the Infosys Prize (2011).

### **43. A. K. Sood (1951- )**



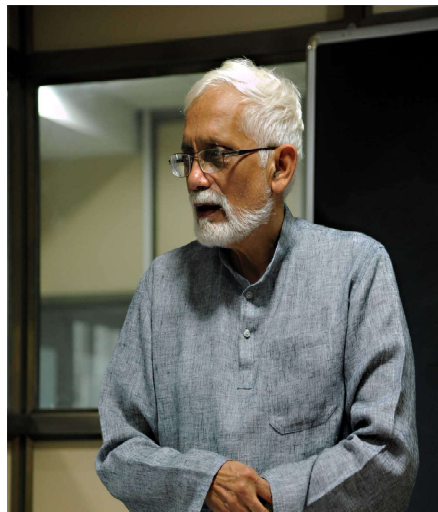
Ajay Kumar Sood is an Indian physicist, known for his pioneering research findings on graphene and nanotechnology. He is a many patents in this field.

Ajay Kumar Sood obtained BSc (Hons) (Physics) (1971) and MSc (Hons) (Physics) (1972) from Punjab University, Chandigarh. He received PhD (1982) from the Indian Institute of Science (IISc), Bangalore. He did postdoctoral work (1983-85) with M Cardona at Max Planck Institut for Festkorperforschung, Stuttgart. Thereafter, he worked at Indian Institute of Science(IISc) Bangalore . Presently, he is Honorary Professor at Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bangalore.

Sood's researches focused on two areas of condensed matter physics; Raman spectroscopy of novel solids, and soft condensed matter physics. His work on resonance Raman studies of semiconductor superlattices clearly brought out for the first time the concepts of confined and interfaces optical phonons. His high pressure Raman studies on fullerenes, solid C<sub>60</sub>, C<sub>70</sub> and single wall carbon nanotube bundles, have brought out many interesting results. He has discovered the new phenomenon that the flow of liquids on single walled carbon nanotubes induces voltage and current in the sample along the flow direction. His other important study relates to the generation of electrical signal by gas flow over a variety of solids, including semiconductors, an effect known as '*Sood Effect*'. Novel nonequilibrium phenomena in the study of colloids in electric field led him to invent an ultra sensitive immunoassay.

The Government of India honoured him in 2013, with the Padma Shri, for his contributions to the fields of science and technology. Sood was elected a Fellow of the Royal Society (FRS) in 2015.

## 44. S. R. Shenoy (1947 - )



Subodh Raghunath Shenoy is an Indian physicist and a former professor at the Tata Institute of Fundamental Research. He has also been associated with the Indian Institute of Science Education and Research, Thiruvananthapuram. Known for his studies on Condensed matter physics and Statistical physics, his research covered topological defect-mediated phase transitions, vortex dynamics and decay kinetics of metastability.

## *Amazing Physics*

Subodh R Shenoy did his B.Sc in Physics at the University of London, and his PhD at Yale University. After a return to India, he has been at TIFR Bombay; the Institute of Physics, Bhubaneswar; the University of Hyderabad; the International Centre for Theoretical Physics, Trieste, and IISER Trivandrum. He is presently a Visiting Professor at TCIS.

The problems he considered for research include: Thermal fluctuations in superconductors; spin glasses; the Kosterlitz-Thouless transition and topological excitations in 2D and 3D XY models; first-passage times and hysteresis; Josephson tunneling in Bose-Einstein Condensates; martensitic structural transitions; and post-quench phase ordering dynamics.

The Council of Scientific and Industrial Research awarded him the Shanti Swarup Bhatnagar Prize for Science and Technology, for his contributions to physical sciences in 1992.

## **45. Deepak Dhar (1951 - )**

**Born: Pratapgarh, Uttar Pradesh**



Deepak Dhar is an Indian theoretical physicist and a distinguished professor at the department of physics of Indian Institute of Science Education and Research, Pune. He is known for his research on statistical physics and stochastic processes.

Deepak Dhar graduated in science from the University of Allahabad in 1970 and got master's degree in physics from the Indian Institute of Technology, Kanpur in 1972. Moving to the US, he enrolled for his doctoral studies under the guidance of Jon Mathews at California Institute of Technology, and after securing a PhD in 1978, returned to India to start his career as a research fellow at Tata Institute of Fundamental Research (TIFR) the same year. After two years of research, he became a full-time fellow in 1980 and served in that position until 1986 when he was promoted as a reader. He had a one-year sabbatical at the University of Paris as a visiting scientist during 1984–85) and a month-long stint at Isaac Newton Institute in May 2006 as a Rothschild Professor. Post-retirement. He continues his association with TIFR as a distinguished professor of the institution.

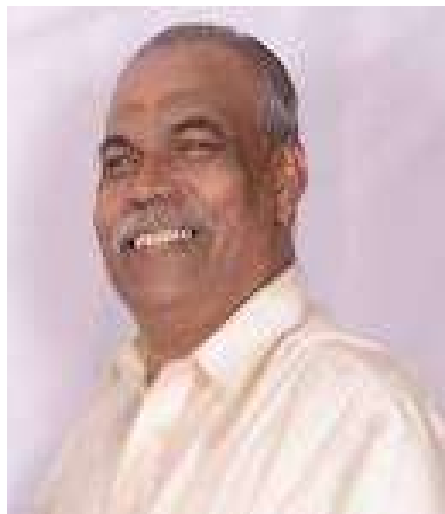
*Amazing Physics*

Deepak Dhar's research is in the area of statistical physics. He has worked on renormalization group studies of critical phenomena on fractals, exact results on the enumeration of

directed branched polymers and directed animals, slow relaxation in disordered magnets, and exact solution of the abelian sandpile model of self-organized criticality. His current interests include models of proportionate growth in biology, dynamics of protein-folding, and theoretical models of super-cooled liquids and glasses.

Dhar is an elected fellow of all the three major Indian science academies as well as of The World Academy of Sciences. The Council of Scientific and Industrial Research, awarded him the Shanti Swarup Bhatnagar Prize for Science and Technology, for his contributions to physical sciences in 1991

## 46. R.Simon (1950 - )



Rajiah Simon, is a Professor of Physics at the Institute of Mathematical Sciences, Chennai, His specialization include Classical and Quantum Optics, Foundations of Quantum Mechanics, and Quantum Information Theory. Simon and collaborators initiated the "Quantum theory of charged-particle beam optics", by working out the focusing action of a magnetic quadrupole using the Dirac Equation.

Rajiah Simon did his BSc (1970) and MSc (1972) from the Madurai University and PhD (1985) from Indian Institute of Science specializing in Theoretical Physics.

R.Simon solved the longstanding problem of reconciling the Heisenberg-Weyl metaplectic structure of scalar Fourier optics with the fundamental Poincare symmetry of Maxwell's equations, and generalized Fourier optics to electromagnetic beams. Simon introduced the concept of time-evolving geometric phase, based on which he designed and performed an experiment to fine-tune the frequency of a laser beam. Simon has developed a new and comprehensive quantum kinematic approach to geometric phase based on the hitherto unnoticed Bargmann invariants, and shown that the classical Gouy effect is the geometric phase associated with the Lobachevskian geometry underlying the metaplectic group. He has proposed a scheme for observing Gouy effect in squeezed light; and has proved that the geometric phase measured in optical interference experiments is the

Hannay angle, not the Berry phase. The deep connection between the real symplectic groups and the Wigner-Weyl-Moyal methods in quantum mechanics and optics have been brought to light in Simon's work. The power of these methods in analyzing multimode noise matrices and squeezing, as well as evolution under quadratic Hamiltonians have been established by him.

Rajiah Simon received the Shanti Swarup Bhatnagar Prize for Science and Technology in 1993 for pioneering work in Quantum optics.

## **47. Mustansir Barma (1950 - )**

**Born: Mumbai, Maharashtra, India**

Mustansir Barma is an internationally renowned Indian scientist specializing in Statistical Physics and condensed matter physics. He was the Director of the Tata Institute of Fundamental Research from 2007 to 2014.

Mustansir Barma did his undergraduate studies at St. Xavier's College, Mumbai and doctoral work at the State University of New York at Stony Brook. After post-doctoral work at Michigan State University, East Lansing, he joined the Tata Institute of Fundamental Research (TIFR), Mumbai in 1976.



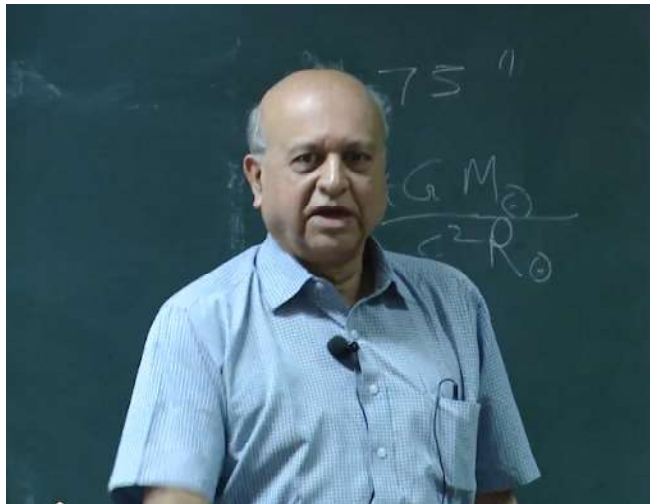
Barma's research is in the fields of Statistical Physics and Condensed Matter Physics. His early work on spin models of magnetism focused on low-temperature properties and on phase transitions and critical point phenomena, while his research on percolation networks was concerned with the effect of frozen-in randomness on disordered magnets and on transport through a badly connected medium. He also worked on finite size effects in Fermi systems, and their influence on the resonant response to electromagnetic radiation. He has been working on the dynamics of deposition and evaporation of bunches of particles, phase transitions in aggregation-fragmentation systems, and on new types of phases which arise when a system of interacting particles is subjected to a randomly

fluctuating potential. His recent interest is in the cooperative aspects of statistical systems driven far from equilibrium.

Barma was awarded Padma Shri in 2013. He received the Shanti Swarup Bhatnagar Prize for the Physical Sciences in 1995.

## 48. Sanjeev Dhurandhar

**Birthplace: Pune, Maharashtra, India**



Sanjeev Dhurandhar is an Emeritus Professor at the Inter-University Center for Astronomy and Astrophysics (IUCAA) in Pune, India. His research interest is detection and observation of Gravitational waves. Dhurandhar was part of the Indian team which contributed to the detection of gravitational waves.

Sanjeev Dhurandhar is one of the pioneers of Gravitational Wave (GW) astronomy in India and has worked extensively on applying advanced mathematical and statistical techniques in developing algorithms for Gravitational Wave searches and detector characterization since the late 1980s. His contributions include introduction of a differential geometric approach to GW data analysis, and the stationary phase approximation to compute the Fourier transform of the chirp.

He was awarded the H K Firodia award for 2016. He is the science advisor to the IndIGO consortium council.

## 49. Sandip Chakrabarty (1958- )

**Born: Malda, West Bengal, India**

Sandip Chakrabarti is a leading Indian astrophysicist, working on various aspects of the field. He is known for Research in black hole Astrophysics, low cost balloon borne science, astrochemistry leading to biomolecules, and ionospheric science.



After finishing his B.Sc. Physics (Honours) from Ramakrishna Mission Residential College, Narendrapur in 1979 Sandip Chakrabarty went to IIT, Kanpur to complete his M. Sc. Degree, which he did in 1981. He joined the Physics Dept. of the University of Chicago to do PhD work. Within a year, a paper was completed with Robert Geroch and X.B. Liang on "Time like Curves of limited acceleration in General Relativity". Chakrabarty was then asked by Prof. S. Chandrasekhar to solve the Dirac Equation in Kerr black hole geometry. In 1984 this work was successfully finished. Subsequently, he concentrated on black hole astrophysics, received his Ph.D. in 1985 and went to Caltech as a R.C. Tolman Fellow. After a brief period at ICTP, Trieste he joined Tata Institute of Fundamental Research in Mumbai in November 1988. Later in 1996 he joined S.N. Bose National Centre at Calcutta.

The main focus of Chakrabarti's research was the hydrodynamic and radiative properties of astrophysical flows around black holes and other compact objects. He showed that the accreting matter must be transonic and should have standing, oscillating and propagating shocks. He wrote the first monograph on "Theory of Transonic Astrophysical Flows" (1990). Chakrabarti was the first scientist to suggest that Gamma-ray bursts are the birth cry of black holes at his presentation in 1995, third Huntsville, Alabama Conference.

Prof. Chakrabarti became closely associated with the Indian Centre for Space Physics (ICSP) of which he is the founding General Secretary and also the head of all the Academic activities. Chakrabarti is involved in research works in several topics which range from Very Low Frequency (VLF) studies of ionosphere, planetary ring dynamics, Astrobiology, X-ray data analysis, testing and evaluation of payloads and developments of detectors for X-ray astronomy.

## **50. A. K. Pati (1966- )**

**Born : Odisha, India**



Arun Kumar Pati is Professor in Quantum Information and Computation Group, at Harish Chandra Research Institute, Allahabad. Earlier he was a scientist at Theoretical Physics Division, BARC, Mumbai from 1989-2010. During his tenure at BARC he was a visiting scientist at University of Wales, Bangor, UK from 1998-2000. Immediately after that he was on deputation to Institute of Physics, Bhubaneswar, India from 2001-2010.

A.K.Pati's research areas include all aspects of quantum information and quantum computation, the theory of geometric phases and its applications, and the foundations of quantum mechanics. Among his important discoveries are the No-Deletion theorem, Geometric Phases for mixed state, Remote State Preparation protocol, the No-Hiding Theorem and the Stronger Uncertainty Relations in quantum mechanics. He has edited two books: (i) *Quantum Information with Continuous Variables* and (ii) *Quantum Aspects of Life*.

A.K.Pati received the 'Samanta Chandra Sekhar Award' from the Orissa Bigyan Academy in the area of physical science (2009). He was honored with K. P. Chair Professor at Zhejiang University, Hangzhou, China (2013-2015).