KARNATAKA PHYSICS ASSOCIATION (R)

(Reg. No. DRB2/SOR/210/2021-2022)

Website: karnatakaphysicsassociation.in

KPA NEWSLETTER – 2 FEBRUARY 2024

FROM THE EDITORS

In this second issue of the quarterly newsletter of KPA we have the eulogy of Prof. G Venkatesh, the founder president of KPA, who passed away most unexpectedly on November 8th, 2023. It is written by Prof. B. S Srikanta, a long-time associate and mentee of Prof. Venkatesh. There is a scientific biography of Prof.B V Sreekantan, former director of TIFR and a close associate of Dr H J Bhabha. It is written by prof. P.R. Vishwanath. It is followed by a biographical sketch of Prof.C V Vishveshwara, popularly known as the 'black hole man of India', who predicted the signature of gravitational waves arising from the merger of two black holes. It is penned by Sri. H.R. Madhsudana. We have a popular article about the life and important contributions of the one and only Isaac Newton written by Prof. B S Srikanta. The next article written by Prof. Kagali is about the not so well known, but remarkable Indian astronomer of the nineteenth century- Pathani Chandrasekara Samanta of Orissa, who did unbelievable work with his crude instruments in a remote part of Orissa. The next article written by Prof.Kagali and Prof. Shivalingaswamy is all about some new and interesting applications of the well-known Bohr's quantisation rule. It shows how one can solve some new problems using only the old quantum theory! It should interest undergraduate students and teachers. Wherever space permits, figures related to the online talks conducted by KPA so far have been inserted.

Next, we have the regular features listing the activities of KPA members as well as online talks held during the quarter from 1 November 2023 to 31 January 2024.

It is hoped that in the coming issues of the Newsletter, more articles will be forthcoming from the KPA members about biographies of physicists, discoveries in physics, new perspectives of teaching old topics, new experiments, round-up of developments in physics, unsolved problems in physics, interesting anecdotes about physicists etc. that should interest and benefit students and teachers alike.

Thanks to Mrs. Muktha B. Kagali for her efforts in designing this newsletter.

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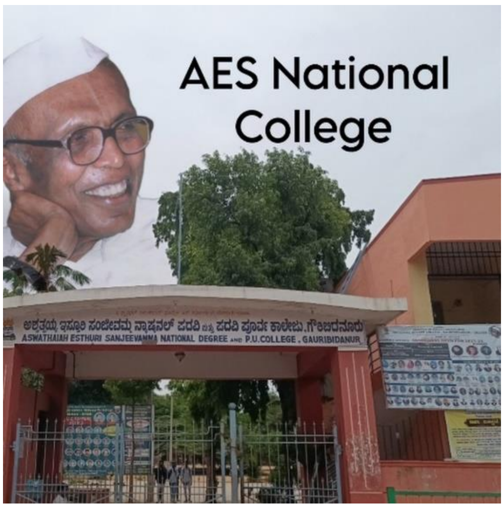
EULOGY TO Dr. G. VENKATESH

With immense grief and sadness in my heart, this eulogy is written to pay tribute to a kind soul, disciplined mind, a good friend, mentor and dedicated teacher of physics Dr. G. Venkatesh, who drank, ate and breathed physics throughout his teaching and administrative career spanning over five decades. I have a reason to make this statement. When he was admitted to a hospital for bypass surgery, he attended an online lecture from the hospital lying in bed. My association with him started way back in 1976 when I joined AES National College, Gauribidanur as a Lecturer in Physics. He was my HOD. It is indeed a very long association of 47 years. Even today, I am not able to digest the fact that he is not in our midst. Personally, it is a great loss to me as he was my mentor, guide and good friend. I owe a lot to him. He motivated me to do a Ph.D. and even introduced me to Raman Research Institute, which I cannot forget in my lifetime.

Dr. G. Venkatesh, most unexpectedly, left for his heavenly abode on 8th November 2023 leaving behind his wife, three sons, daughters-in-law, grandchildren and a host of relatives, friends, students and admirers. His sudden death has put his family members, students, friends, admirers and associates in a deep sense of sorrow and pain.

Dr. G.Venkatesh was born on 18th October 1945 as the second child to his parents Sri Gundu Bhatta and Smt. Kamalamma. He had his early education at Gauribidanur. He was a



brilliant student right from his childhood. He joined The National College, Basavanagudi, Bangalore in 1962 and completed his B.Sc. degree in 1965 securing distinction. He completed his M.Sc. from the University of Mysore in 1967 specialising in Theoretical Physics. In the same year, he joined AES National College, Gauribidanur as a Lecturer in Physics and continued to serve the institution till 1992. During his long stint of 25 years at AES National College, he adorned various positions – Lecturer, Reader, Head of the Department, Professor and Principal. He was undoubtedly an inspirer to all those associated with physics. He was highly adored by his students for his excellent teaching, scholarship and deep understanding of concepts in physics. He had earned appreciation from his students for his erudition and sagacity. Many of his students have reached pinnacles in their careers occupying top positions in several organisations. He also impressed the management and his colleagues with his administrative acumen.

During his tenure at AES National College, he also obtained a Ph.D. degree from Bangalore University by carrying out research work at the internationally known Raman Research Institute between 1977 and 1980 under the guidance of a renowned scientist Dr. S.Chandrashekar for his thesis titled "High-Pressure Studies on Liquid Crystals." He had published several research papers and articles in national and international journals. I feel proud to record that we both co-authored four textbooks in physics for B.Sc. classes.

After taking voluntary retirement from AES National College, he served in Bhagavan Mahaveer Jain College, Garden City College and Indian Academy Degree College as professor and principal for nearly two decades. The management of these institutions for his ethical administration and good governance appreciated him. He was a visionary and true academic leader who introduced several constructive reforms in the institutions he served. He was on the Board of Management of the Indian Academy Group of Institutions as an Academic Advisor till his last days.

Delving into his academic and co-curricular activities, is indeed mind-boggling. He was involved in a very wide spectrum of academic activities. I distinctly remember, that when he was the President of the Karnataka Rajya Vignana Parishath, Gauribidanur unit, he had formed a team of speakers, which included me also, to deliver lectures on scientific topics in all high schools in the taluk. We used to visit high schools in the taluk every week, carrying all the required paraphernalia like slide projectors etc., and deliver lectures to create interest in science amongst students. He was very passionate about popularising science in general and physics in particular among students and teachers. He was greatly involved in this academic pursuit, which was dear to his heart till the last moment of his life. He used to derive immense pleasure in delivering popular lectures.

In the later part of his illustrious career, he served as the President of the Indian Association of Physics Teachers (IAPT) RC12A and also as national level Chief Co-ordinator of IAPT examinations. With his meticulous handling, many folds enhanced credibility and the office bearers and members of the association appreciated the fairness of the examinations and the same.

His dream was to start an association at the state level and hence create a platform to propagate and popularise physics and physics education. With his indomitable spirit, he could pool in a team of like-minded people and succeeded in establishing the Karnataka Physics Association (KPA) just a year ago. Many physics enthusiasts joined hands with him in this academic venture. Within a year, the association has witnessed a phenomenal growth. Dr. G. Venkatesh was instrumental in organising several programmes under the umbrella of KPA. His energy and enthusiasm were astounding, something unimaginable.

Dr. G. Venkatesh popularly known as Dr GV among his friends, associates and students was a man of action, a dedicated and committed teacher, a scholar in physics, a good orator, an able administrator, a good organiser, a great leader with impeccable character and a man of high integrity. He was the epitome of all these virtues. Because of his honesty and integrity, he could talk to any person either his subordinate or higher authority with courage and conviction.

In the untimely death of Dr G. Venkatesh, we have lost a great inspirer and a mentor. It is difficult to fill the void created by his death. Though physically, he is not in our midst, I am sure that his spirit will be always behind us to guide us in our pursuits. Let us carry forward the legacy left behind by him.

On behalf of all his friends, students and associates, I express my deepest condolences to the bereaved family and pray to God to give adequate strength to bear the irreversible loss, a word that I have taken from Thermodynamics, a branch of physics dear to Dr GV's heart.

I conclude with a quote by Cicero (Roman statesman and philosopher)

"The life given by nature is short, but the memory of a life well spent is eternal"

Author: Dr (Prof). B.S. Srikanta
Principal (Retd), RBANMs. College
Former Academic Director and Principal, Surana College
Former Director and Principal, Sindhi College, Bengaluru

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PROF. B V SREEKANTAN: A PIONEER PHYSICIST

Prof. B.V. Sreekantan (1925-2019) was a well-known experimental physicist who passed away at the age of 94 on 27 Oct 2019. He did many pioneering experiments in the field of particle physics and astrophysics which address the micro and macro aspects of the universe respectively. His experiments are important because these were pioneering efforts of an individual as also of a new institution and importantly, they point to independent research in a poor country looking for new ways and means.

Early education:

B (Badanaval). V (Venkata). Sreekantan was born into an erudite family at Nanjanagudu, where Sreekantan's father, Sri B.V. Pundit (1887-1975) was a well-known Ayurvedic physician and was also manufacturing tooth powder, famous not just in erstwhile Mysore state but also beyond. Sreekantan was one of the eleven children; eight boys and three girls. He was the fifth child and was born on 30 June 1925. Sri Pundit was also well known for his philanthropy and was looked up to as an elder statesman of the town, who arranged interesting events in his home including lectures on various subjects. Also, there used to be regular discussions on many subjects at home among the members of the family. Thus, all the children in the Pundit family were exposed to an atmosphere of learning from an early age.

Sreekantan's initial schooling was done at Nanjanagudu and later at Mysore (Yuvaraja's College, 1942-1944) and Bangalore (Central College, 1944-1947). Immediately after his M. Sc., Sreekantan joined the Communication Engineering department at the Indian Institute of Science (IISC) in August 1947 where he got a good foundation in electronics. However, his interest was in physics and he went to Mumbai to join the Tata Institute of Fundamental Research (TIFR).

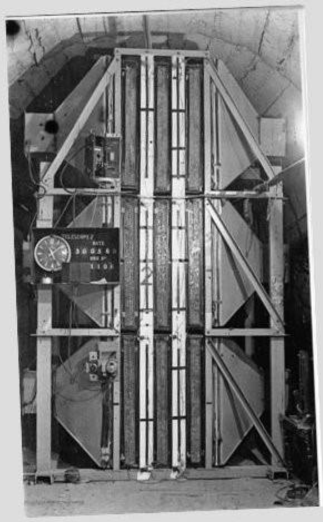
Homi Jahangir Bhabha (1909-1966), who studied in England in the 1920s and wrote seminal papers on several aspects of Cosmic Ray and Particle Physics, came back to India and worked at IISC in Bangalore for some time. Later, he started TIFR in 1945 at Mumbai, which was on the lines of the best institutions in the west. In the initial years, he recruited several bright young men who, eventually, went on to lead activities in their respective disciplines in the country. One such was this young man from Mysore who did well in the interviews and took up experimental work based on Bhabha's suggestion.

One of the premier areas of research at that time was experimental particle physics and Cosmic Rays. Particles, which are the constituents of matter like the electron, the proton, and the neutron, had all been discovered in England by the 1930s. However, Cosmic Rays, discovered in 1912 and which are mostly protons from outer space, interact with various nuclei in the atmosphere and produce a very large number of secondary particles which come down to the ground level. Many new particles had actually been discovered among these secondaries: For example, positrons which were explained as anti-electrons, Pi Mesons, which were explained as carrier particles of nuclear force and which operate between nucleons, are some of them. Of all the particles at that time (~1950), one the most interesting was the muon, which was a part of the hard component of secondary Cosmic Rays and which could penetrate large amounts of matter, but had seemingly no role in the scheme of particles.

Particle Physics Experiments:

These new particles like the pi and muons (called mu mesons in the initial days) had masses in between that of the proton and the electron and unlike them, were not stable and decayed, their lifetimes being of the order of micro and nano seconds. The lifetime of the muons was still not well-established due to discrepancies among different experiments. Sreekantan's first experiment was to find the lifetime of muons. This experiment required building of GM (Geiger Muller) counters for their detection and also various electronic circuits like pulse electronics, coincidence circuits, etc., with better than microsecond capability. All these had to be built in the laboratory from scratch and Sreekantan and his colleagues ingeniously faced these problems. The experiment, which required about three years, was considered as one of the most sophisticated Cosmic Ray experiments of that time. Based on this experiment, Sreekantan derived the lifetime of positive muons to be *2.24 +/- 0.15* microseconds which is close to the modern value of 2.197083 +/- 0.000015 microseconds.

The next series of experiments by Sreekantan and his colleagues were done in the gold mines at KGF, 100 kilometers from Bangalore. The mines, started more than 100 years ago, had many shafts, which would go underground, and many kilometers of underground tunnels where experiments could be set. This was ideal for the further study of muons since they have an interesting property. They can pass through the top layers of the earth and then keep going underground. The TIFR physicists took their measuring equipment to various levels in KGF and found out that the number of muons kept going down as they went deeper and deeper. Sreekantan analysed this data by 1953 and obtained his Ph. D. from Bombay University. Bhabha was his guide and the renowned Cosmic Ray physicist Bruno Rossi of MIT was his external examiner.

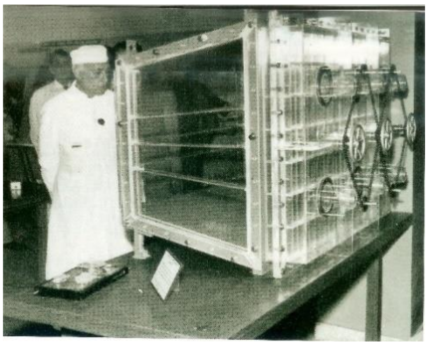


KGF ν detector

(*The experimental set up in the atmospheric neutrino experiment at KGF; the detectors (parallel to the wall) are plastic scintillation detectors; horizontal neutrinos coming from the sides were recorded.*)

Neutrinos, proposed as early as 1932 as neutral particles with very little mass, were discovered first in 1955. It was found out in 1962 that there were two types of neutrinos - electron neutrino and muon neutrino. Both these experiments connected with the artificial neutrinos received Nobel Prize later. However, there are natural neutrinos among particles produced in Cosmic Ray interactions in the atmosphere and they travel large distances without interaction which are aptly called Atmospheric neutrinos. With the group's further experiments showing minimal presence of other particles including muons deep underground, it became very obvious that the deep mines in KGF, with very minimal background, were the right place to search for atmospheric neutrinos. An experiment was conducted at KGF in 1965 by a collaboration involving TIFR, British and Japanese physicists. Several atmospheric neutrinos were, indeed, discovered and recorded. The results of this path-breaking and possibly Nobel prize worthy experiment of which Sreekantan was an integral part were received very well by the community. KGF mines were used again in the 1980s for another important experiment; to look for the decay of proton, considered stable till that time. The importance of this experiment was that it set the limits on the lifetime of protons and the efforts which went into the experiment showed that the country was capable of building huge experiments with modern techniques.

The detailed study of the particles was shifted to the accelerators in the 1950s. Cosmic Ray experiments remained relevant since they were of much higher energy with the possibility of finding out the higher mass particles and other interesting phenomena. It was also necessary to understand particle interactions at energies much higher than those available in accelerators. It was realized that the study of Extensive Air shower (EAS) phenomena (simultaneous arrival at detectors of a very extensive group of particles, in thousands and more) would give information on both high-energy interactions and primary Cosmic Ray composition. The beautiful hill station of Ooty (~2.3 km asl) in Tamil Nadu was chosen by Bhabha and Sreekantan for the studies of both High Energy Interactions and EAS. The highlight of the work at Ooty was that of innovative instrumentation. TASS, a total absorption spectrometer, was built with alternate layers of iron and scintillators to determine the energy of the Cosmic Ray particles impinging on the instrument. It should be noted that this was the forerunner of the ubiquitous calorimeter present in all high energy physics (HEP) experiments today. A Cerenkov counter and a big multiplate cloud chamber, the largest of its kind in the world at that time, were also built. A combination of all these instruments was used to study the characteristics of hadrons (protons, neutrons, pions etc.). New experiments involving a huge number of particle detectors called plastic scintillators were set up at Ooty and KGF for the study of different aspects of EAS. New electronic circuits for nanosecond phenomena were designed and built for these experiments. Another novelty was the use of Monte Carlo calculations which were detailed simulations of processes in the generation and detection of particles. The TIFR group was one of the first to set up the code for these calculations which were to be repeated later in many Cosmic Ray experiments. Important results on high energy interactions and primary Cosmic Ray compositions were obtained by these studies.



Prime minister Nehru looking at the model of the multiplate cloud chamber, the largest of its kind, which was used in the experiments at Ooty.

High Energy Astrophysics experiments:

The 1960s saw the birth of two major activities in astronomy, both connected to high-energy phenomena; ‘X-ray and Gamma ray Astronomy’. These fields were connected to violent activities in celestial objects and were later found to be ideal for studies of black holes, quasars, etc. Detection of copious X-rays from a celestial source (Sco X1) was observed in 1962 by the MIT group, which heralded the birth of X-ray Astronomy. Sreekantan realized that studies of hard X rays (>30 KeV) could be done in India with balloons and that the observations would be of longer duration compared to rockets. Several interesting results like the emission from the black hole candidate Cyg X-1 were obtained by the group.

The possibility of Very High Energy (VHE) - >100 GeV - Gamma ray emission from celestial sources was explored in the early 60s with the use of Atmospheric Cerenkov technique (ACT) where Cerenkov radiation produced in the Earth’s atmosphere by Cosmic and Gamma Ray particles was detected using simple and large parabolic mirrors. The TIFR group entered this field in 1968 and eventually had an eighteen-mirror array at Ooty and thereby significant results were obtained on gamma ray emission from pulsars. Sreekantan and his colleagues pioneered these studies. The experiment was shifted to Pachmarhi in MP which made it possible for observations to be conducted for a much longer time.

The Mirror array used for the studies of VHE gamma rays at Ooty and later at Pachmarhi; the mirrors collect Cerenkov radiation emitted by particles in the atmosphere and the light is converted into electric signals by a device called photomultiplier kept at the focus of the mirror.

After Homi Bhabha and M. G. K. Menon Sreekantan became the director of TIFR in 1975 and he held this position for the next twelve years. He was responsible for starting new activities like the Giant Meter Wave Radio Telescope (GMRT), Pune, National Centre for Biological Science (NCBS), Bangalore, Homi Bhabha Centre for Science Education (HBCSE), Mumbai, etc. He was very much respected and liked for his leadership qualities and also because he could be approached at all times. He was also the Chairman of the Governing Council of the

Indian Institute of Astrophysics (IIA) for several years where he initiated several new programmes. He received several professional awards like the R. D. Birla Award of the Indian Physics Association, the *Padma Bhushan*, etc. After moving to Bangalore in 1992, he joined the National Institute of Advanced Studies (NIAS) where he started scientific and philosophical studies on consciousness and exploration of commonalities and similarities in holistic approaches in modern science and ancient philosophies. Till the very end of his life, he was very busy with the work at NIAS. He was mentally very alert and even when he was in his nineties, he worked in the institute from 9 AM to 5 PM.

Sreekantan's Legacy:

It is important to note that most of the programmes started by Sreekantan became larger as time passed not only in India but also elsewhere and some, who worked on those programmes, have, indeed, received Nobel Prizes. This shows that Sreekantan was very much aware of the importance of these experiments in the realm of knowledge. The neutrino experiment of KGF became the forerunner of huge experiments in Japan, the USA, Canada, etc., later, which saw oscillations in atmospheric neutrinos and solar neutrinos. The number of celestial X-ray sources, from a handful in the 1970s, has increased to more than a lakh and importantly, have given seminal information on high energy astrophysical processes. The TeV (VHE) Gamma ray programme at TIFR was shifted to Hanle in Ladakh, thereby achieving low threshold energy and a new array was built which gave interesting results. From a lone significant source in the late 1980s, the total number of VHE gamma ray sources is more than 200 today. The EAS array at Ooty with 400 + detectors has also given very interesting information on solar flares. The high points of High energy physics studies were the discoveries of the Top Quark and the Higgs Boson where there was significant Indian participation in both these ventures in instrumentation and analysis. Apart from these individual programmes, increase of interest in experimental research in the country also is Sreekantan's lasting legacy.

Here is Sreekantan about experimental research: *Without instrumentation it is impossible to do any fundamental research and this has become obvious in the last century or so. The more sophisticated instrument that you have, the higher the quality of research that you can do. In fact, compared to other institutions in India the reason TIFR stood out in the earlier days was essentially because it was able to develop these instruments in all the fields.*

Author: Palahalli R. Vishwanath (prvishwa@yahoo.co.in) obtained his Ph. D. from the University of Michigan, USA and was a professor at the Tata Institute of Fundamental Research, Mumbai till 2002 and later a visiting professor at the Indian Institute of Astrophysics, Bengaluru. He has worked on about ten large-scale experiments in the fields of Cosmic Rays, High Energy Physics, and High Energy Astrophysics in the USA and India. His last project was setting up an observatory at Ladakh in the High Himalayas. He has been a science communicator in both English and Kannada. He is also the author of eight books on astronomy and physics in Kannada. He has taken part in many TV programmes dealing with physics and astronomy. He visits schools and colleges to give lectures and interacts with young students.

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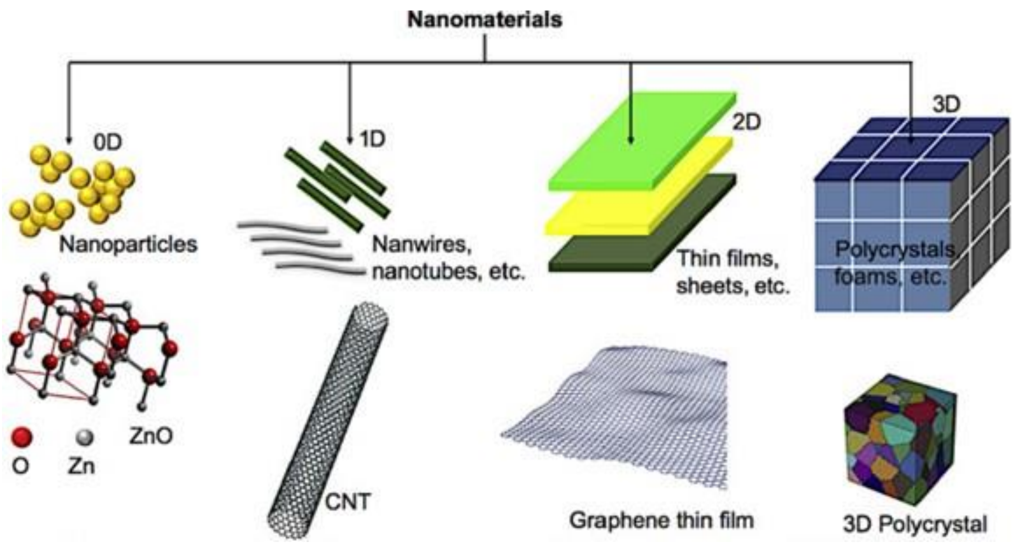

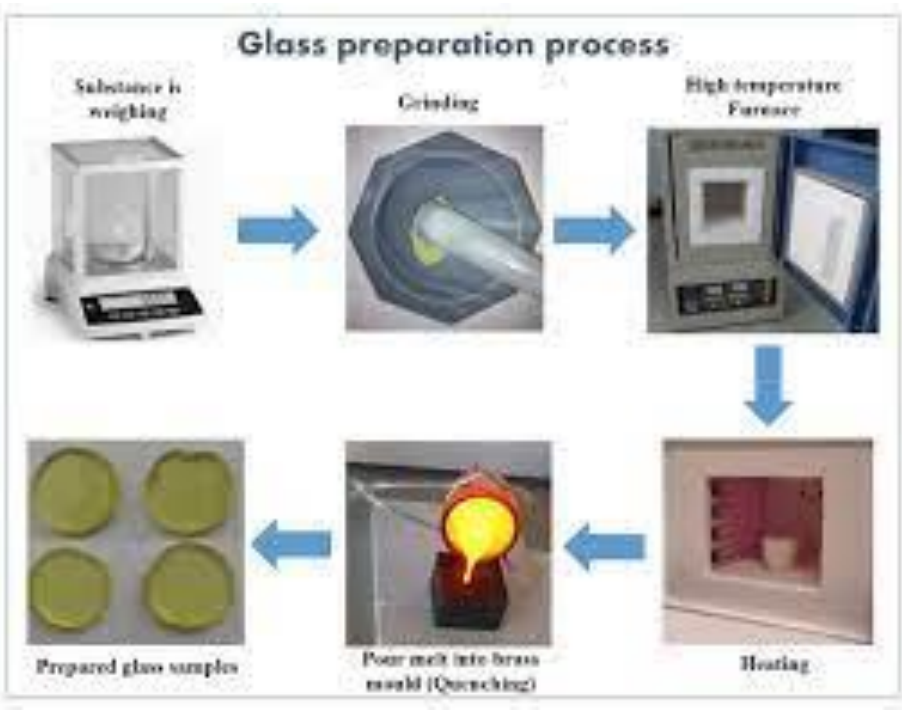

C.V. VISHVESHWARA – THE BLACK HOLE MAN OF INDIA

C.V. Vishveshwara – popularly addressed as CVV or Vishu passed into another universe on January 16, 2017, perhaps altering the spacetime curvature that he fondly studied for over five decades.

This is a small tribute to the great friend, philosopher and guide who had so many like me, in every sense of the word. (!!)

Vishveshwara is very well known in scientific circles both as a rigorous researcher and as a 'Science Popularizer'. His name is as popular as the science that he popularized. It is another thing that he did not go after popularity.

Prof. C. V. Vishveshwara was born to Sri C.K. Venkata Ramayya and Smt. K. Venkatsubbamma in Bangalore on 6th March 1938. His primary education was in Bangalore. He obtained BSc (Hons) in 1958 and M Sc. in 1959 from Mysore University. He received his A.M. degree from Columbia University, New York in 1964. He acquired Ph. D from University of Maryland, USA in 1968.

Prof. Vishveshwara started his career as a Post-doctoral fellow and served as a visiting faculty member in the University of Maryland. He was a NAS-NRC Resident Research Associate at the Institute for Space Studies, New York 1968-69. He was an Associate scientist at Boston University (1969-72); a senior Research Fellow in New York University (1972-74) and a Visiting Associate Professor at University of Pittsburgh (1974-76). He joined Raman Research Institute in October 1976 as an Associate Professor. He became Professor in 1980. He moved to Indian Institute of Astrophysics, Bangalore in December 1992 as a Senior Professor.

Prof Vishveshwara was visiting faculty at the University of Pennsylvania, Philadelphia, USA (1980 – 1983), University of Maryland, College Park, USA (August 1985 – January 1986), Inter-University Centre for Astronomy and Astrophysics, Pune (1990-1993).

Apart from regularly teaching courses in general relativity, various types of educational activities have been pursued by Prof. Vishveshwara, which include organizing and directing special schools like Summer Institute in Relativity at Madurai in 1984; Instructional Conference on Gravitation, Gauge Theories and the Earth Universe at Bangalore in 1986 and Inter-University Graduate School in Gravitation and Cosmology, Pune, 1989. He was also involved in the preparation of the Eleventh and Twelfth standard physics text books brought out by National Council of Educational Research and Training. He established the Planetarium at Bangalore and was the Founder Director of the Planetarium during November 1987 to March 1990.

Prof. Vishveshwara has worked extensively on the theory of black holes, making major contributions to this exciting field of research since its very beginning. He was one of the first to analyze the structure of black holes employing space-time symmetries thereby demonstrating the existence of the ergosphere. He proved the stability of the non-rotating Schwarzschild black hole, a crucial factor that ensures its continued existence after formation. Further, he discovered the quasinormal modes of black holes. These modes of black hole vibrations would be one of the main targets of observation when the gravitational wave detectors, being set up all over the world, become functional. In recent years, he was investigating black holes in cosmological backgrounds, an important aspect of black hole physics that has hardly been explored. Vishveshwara has also made significant contributions to other areas of general relativity.

Prof. Vishveshwara was elected as the Fellow of the Indian Academy of Sciences, Bangalore in 1977. Prof. Vishveshwara held membership of many learned bodies such as - American Physical Society; International Astronomical Union; Advisory Committee on Gravitation and Cosmology; University Grants Commission, Government of India; Executive Council, Internal Society for General Relativity and Gravitation; Steering Committee and Governing council of Inter-University Centre for Astronomy and Astrophysics, Pune; Science and Technology Advisory Council, Government of Karnataka.

To paraphrase Einstein, one of the three scientists whom he admired most (Galileo and Newton were the other two) : ‘To punish Vishveshwara for his contempt for popularity, God made Vishu popular’*. He became popular for his witty ways in which he laced hard-core science with humorous anecdotes and analogies. You mention his name and invariably the person who has heard CVV before will immediately recall his sense of humor. That was a standout character of his presentations.

But then, beneath that thin layer of humour lay the actual flesh and blood of ideas that he wanted us to comprehend. Once, while talking about the ultimate fate of the universe, CVV mentioned the competing theories and he pointed out one that, he felt, would be the correct course for the universe. When questioned by someone in the audience as to how he knew the answer, CVV shot back ‘…because I am the Lord of the Universe!’. All of us, who knew that he never indulged in self-glorification, were taken aback at this brazen declaration. With that characteristic pause and inimitable intonation, he added, ‘After all, my name is Vishveshwara, meaning Lord of the universe!’. The audience always enjoyed this kind of unexpected, ‘serious’ one-liner from him. I may not be wrong if I say that a good number of students would have been disappointed without those one-liners.

CVV was fond of quoting others’ ideas as well. He had a rich collection of real gems of quotations. He was once asked about what the God was doing before he created the Universe (Bing Bang). He quoted St. Augustine and said ‘God was preparing Hell for those who asked such questions!’

Vishveshwara's contribution to education is immense. Instead of blaming the ills that plagued the education system, he conceptualized a series of educational programmes at JN Planetarium, Bengaluru, of which he was the director. All these programmes have grown in stature and made an everlasting impact on the right kind of students. Several students have been motivated and inspired to take to pure science - research and teaching during the last two decades and some of them are faculties in reputed research institutes and universities and deeply involved in teaching the same programme or course that once nurtured them.

CVV's impact on students cannot be quantified but one just has to hear from them directly. As the Director of Planetarium, he scripted not only several programmes that brought joy to visitors but also guided the manner in which all activities were to be conducted. His taste for aesthetics, music, literature and fine art are shining brightly in the scripts of the planetarium shows. They made our shows unique and drew praise from legends such as S. Chandrashekar, Roy Kerr, Alan McKay and Anthony Legget – all big names in science, which they practised.

CVV was not in good health for the last nine months prior to his death. During that period, I went to meet him just twice. And, on both the occasions, struggling to speak, he enquired about my family – my daughters and wife. His caring attitude was not restricted to his colleagues and their work but went beyond that. He knew every family member of every colleague of his.

Well in writing these random thoughts (well, how can one organize thoughts when one is shell-shocked with the news of his passing away?) I have broken one dictum of his: A good write-up must have a good beginning and a good end and keep these two close to one another. I have breached all these requirements.
Sorry, CVV Sir

*Actual statement made by Einstein is reproduced here: "To punish me for my authority, fate has made me an authority myself". Aphorism for a friend, 18th September 1930. Einstein Archive 36-598; as quoted in Albert Einstein: Creator and Rebel, 1988, Banesh Hoffman.

Authors: H.R. Madhusudan and inputs from others.

Sri H. R. Madhusudan (pallavimadhusudan@yahoo.co.in) worked for close to three decades at the Jawaharlal Nehru Planetarium, Bengaluru, planning, coordinating and teaching in all its educational and popularization programmes until his superannuation. He is, currently, a Visiting Faculty at JNP and continues to teach.

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NEWTON, GRAVITATION AND OPTICS

Sir Isaac Newton was a brilliant English physicist who lived in the second half of the seventeenth century and first quarter of the eighteenth century (1642-1726). He was not only a physicist but also a mathematician, astronomer, natural philosopher (During Newton's time, word Scientist was not in science diction). All Scientists were called natural philosophers! The word “Scientist” was coined in 1834 by William Whewell, a Cambridge University historian and philosopher of science) and an alchemist. Newton is best known for his theory about law of gravity and laws of motion. His magnum opus "Principia Mathematica published in 1687 with description about the laws of motion and gravity ushered in renaissance of enlightenment in Europe in particular and in the world in general. The publication of Principia is a culmination of years of research that established the universal laws of motion and gravity. He is very often referred to as "Father of Classical Mechanics". The second major book titled "Opticks" by Newton deals with properties of light. He also served as the President of the Royal Society of London and Master of England's Royal Mint before his demise in 1726.

EARLY LIFE

Isaac Newton was born on 25th December 1642 (Julian calendar) in a tiny hamlet of Woolsthorpe, Lincolnshire, England. It is interesting to note that in the same year Galileo had died (8th January 1642). Sometimes, it remarked that, perhaps, God did not want to have vacuum in the field of physics and ensured that Newton was born in the same year. His father Isaac Newton (Father's name was also Newton) had died three months before Newton was born. His mother was Hannah Ayscough. As a very tiny and weak baby, everyone thought Newton would not survive for a long time, even his first day of life. It is recorded that baby was so tiny that it could be fitted into a big tumbler but God's will was different. Newton lived for nearly eighty five years.

Newton's widowed mother married a well-to-do man Barnabus Smith within two years of Newton's birth. His mother left young Newton with his maternal grandmother and moved to a neighbouring village with her second husband. Thus, Newton was deprived of love and affection of both his parents. It is said that this deprivation of parental affection had a profound psychological influence on Newton. He grew in his grandmother's place for about nine years until the death of his step father in 1653.

Newton had his early education in village schools. He studied in King's School, Granthum. In 1659, he was taken back to his home town and his mother very much wanted him to become a farmer but Newton was very much unhappy with the proposal and abhorred it. In 1661, he joined Trinity college at the University of Cambridge at the age of nineteen years. When Newton joined the university, the teachings were based on those of Aristotle, but Newton preferred to read more of advanced ideas and concepts put forth by modern philosophers such as Descartes, and astronomers such as Galileo (Italy), Copernicus (Poland) and Kepler (Germany). Newton obtained his degree in 1665 and in the same year University was closed for about eighteen months as a precaution against the great plague. For the next two years, Newton worked at his home at Woolsthorpe on Calculus, Optics and Law of Gravitation.

Gravitation: Universal law of gravitation as enunciated by Newton states that "Every particle attracts very other particle in the universe with a force proportional to the product of their masses and inversely proportional to the square of the distance between them ".

While he was pensively meandering in his family's apple farm, it came to his thought that the power of gravity, which brought apple from a tree to the earth and made it to fall perpendicularly to the earth's surface, was not limited to a certain distance from the earth but this power should extend much farther than was originally thought.

The analysis of circular motion in terms of Newton's Laws of Motion brought out the point that centripetal force in necessary to divert a body from its rectilinear path. Further, he found that the centripetal force responsible for holding planets in their elliptical orbits about the Sun varies inversely as the square of the planet's distance from the Sun. He also argued that as satellites of Jupiter obey Kepler's third law, inverse square centripetal force keeps them in their elliptical orbits.

Newton's deduction revealed that a similar relation exists between the earth and the moon. The distance of the moon from the earth (384401 km) is nearly 60 times the radius of the earth (6371 km). He also found that the ratio of the acceleration due gravity on the earth's surface (a_e) and that at the moon's distance (a_m) is approximately 3600 (60^2). Thus, the ratio of acceleration due to gravity ($9.81 m/s^2$) on the earth's surface to that at the distance of the moon (2.72×10^{-3} m/s^2) is equal to the square of the ratio of the radius of the moon's orbit to the radius of the earth. This equivalence of the ratios suggests that the acceleration of an object decreases in inverse proportion to the square of its distance from the centre of the orbit. Since the force is the product mass and acceleration, gravitational force must also vary inversely as the square of the distance. Thus, Newton discovered Universal law of Gravitation. Newton used Kepler's II and III laws of planetary motion to deduce the theory of gravitation. Further, Newton realised that gravitational force between bodies must depend on the masses of the bodies. Since a body of mass M experiencing a force F accelerates at a rate F/M, a force of gravity proportional to M would be consistent with Galileo's observation that all bodies accelerate under gravity toward the earth at the same rate, a fact which was tested experimentally by Newton also .Mathematically , Newton showed that gravitational force should be proportional to the product of the masses of the bodies

Newton showed that orbital path is an eclipse under the action of inverse square law. Further, he showed that the motions of object on earth and of celestial bodies are governed by the same set of laws by demonstrating consistency between Kepler's law of planetary motion and his theory of gravitation. Force of gravity is present between stars, galaxies and all celestial objects.

In 1684, Edmund Halley asked Newton about what orbit a body followed under the inverse square law? Newton instantaneously replied that it would be an ellipse. Using his theory of gravitation Newton derived Kepler's laws of planetary motion, accounted for tides, paths of comets etc. Most importantly, these formulations confirmed heliocentricity of the Solar System.

Edmund Halley used Newton's method and found almost parabolic for a number of comets but when he computed the orbit of those comets that appeared in 1537, 1607 and 1682, he found they were the same comet. The same comet had appeared in 1456 and 1378. Further, he predicted that the same would appear in 1759 and it did appear in 1759. As we know, it appeared in 1986 and next will appear 2061. It is the well-known Halley's comet.

Let us digress, a little, and try to learn about the impediments for the new theory of gravitation.

The main hurdle for the development of the new theory was Aristotle's argument and Descartes's Vortex Theory of Gravitation.

Aristotle's arguments were - (a) A body falls because it has the nature in it, (b) Heavenly bodies execute circular motion (c) A body moving at constant speed needs a continuous force acting on it to maintain the speed and the motion, (d) Force can be applied to an object only through contact (e) Heavier objects fall with greater speeds than the lighter ones.

Again, according to Descartes vacuum could not exist. The space is filled with ethereal matter consisting of eddies and vortices which cause gravity.

With the discovery of law of gravitation by Newton all the above arguments were totally discarded.

Another topic that deserves a brief mention is Einstein's modification of Newton’s Law of Gravitation.

The general theory of relativity, formulated by Einstein in 1915, he approaches gravitation in a different way. Newton's law of gravitation accurately predicts the motion of planets in our solar system. Nevertheless, several phenomena like of orbit of mercury and the effect of gravity on light have shown discrepancies from what is predicted by Newton's laws.

In 1905, Albert Einstein formulated his Special theory of relativity, which fixes speed limit in the universe. No motion can exceed the speed of light. The principles of Newton's Mechanics fail when we approach the speed of light. Newton's law of gravitation has an inherent assumption of action at a distance. According to this assumption, displacement of one mass is instantaneously communicated to other masses. Einstein argued that signals couldn’t be sent at a speed faster than the speed of light. Newton's theory has no answer for this. According to General theory of relativity, there is no difference between uniform gravitational field and uniform acceleration in the absence of gravity. According to Einstein's theory, gravitation is not a force between two objects, but is the result of an object responding to effect of the other on the space-time surrounding the object. Gravity produces curvature in the space around a massive body. Euclidean geometry assumes a flat space. But the general theory of relativity challenges this aspect. It states that only empty space in flat. The presence of mass curves the space from around it. The motion of any other mass is just a response to the curved space-time. Einstein’s theory further predicted that light ray should bend or deflected while passing in the proximity of a gravitational mass. The gravitational bending of light was confirmed by Sir Arthur Eddington by observing the bending of star light (Pleiadas in Taurus) while passing by the Sun during total solar ellipse of May 29, 1919, thus providing proof of Einstein’s prediction.

Optics: Newton’s first work as a Lucasian Professor was on Optics.

In 1666, Newton observed that a prism refracts different colours by different angles. This fact made Newton to conclude that colour is a property intrinsic to light. Newton investigated the refraction of light and demonstrated that white light passing through a prism splits into its constituent colours producing a multi coloured image which he called spectrum. He also showed that the colours could be recomposed into white light by using a lens and a second prism. He discovered that white light consists of seven colours viz, VIBGYOR. Further, he observed that colour is the consequence of objects interacting with the coloured light and not the objects producing colour themselves. This is called Newton's theory of colour. Newton concluded that any lens used in a refracting telescope suffers from the defect of chromatic aberration. This made him to construct the first reflecting telescope. He used Newton's rings, which is very familiar to all physics teachers, to test the quality of optics. He was elected Fellow of the Royal Society of London after the invention of reflecting telescope. It is worth mentioning here that, earlier to Newton's work every scientist including Aristotle were of the opinion that white light was a single entity.

Newton is also known for his corpuscular theory of light. He argued that light consists of particles or corpuscles (not to be mistaken for photons) and were refracted by accelerating towards a denser medium. These particles are so tiny that they can travel through the interstices of the particles of matter with the velocity of light. When these particles fall on the retina of the eye, they produce the sensation of vision. Though the theory could account for the optical phenomena like rectilinear propagation of light, it could not account for simultaneous reflection and refraction. Also, according to this theory, light travels faster in a denser medium than a rarer medium which is contrary to the experimental observation. Further it could not explain interference and diffraction. Hence, Newton's corpuscular theory, which was documented by Newton in his book titled "Opticks" and published in 1704, was discarded.

Newton's theory of Gravitation predicted that the path of any material particle moving at a finite speed is affected by the force of gravitation. In Newton's time, finite speed of light was not yet well established. Based on the corpuscular theory of light, though Newton predicted the bending of light, Newton could not make any definite prediction about whether light is affected or not by gravity. At the end of his treatise on Opticks published in 1704, Newton has said, I quote "not now think of these things into farther consideration". He also proposed a query, I quote "Do not bodies act upon light at a distance, and try their action bend its rays, and is not this action strongest at the least distance". Based on corpuscular theory of light, Soldner, in his paper published in1804, concluded that heavenly bodies would divert light. He calculated the deflection by the Sun to be 0.84 arc seconds, half of what Einstein predicted in 1916 on the basis of general theory of relativity(1.7 arc seconds). This is the verified by Eddington in 1919.

Apart from gravitation and optics, he also formulated an empirical law of cooling and & studied the speed of sound in gases.

Newton occupied several prestigious positions in the government. He held the post of warden of the Royal Mint from 1696 to 1699 and Master of the Royal Mint from 1699 to 1726, President of the Royal Society from 1703 to 1726, Member of Parliament of the University of Cambridge from 1689 to 1690 and 1701 to 1702. He was knighted by Queen Anne in 1705.

The Principia Mathematica is regarded as one of the most monumental works in the history of science. It is a book by Newton, which expounds Newton's law of motion and his universal law of gravitation. The book written in Latin was published in 1687. Edmund Halley assisted and persuaded Newton to publish this book and even he bore the cost of publication.

French Mathematician Lagrange has said, I quote, “Newton was a great genius who ever lived and once added that he was the most fortunate, for we cannot find more than once a system of world to establish".

English poet Alexander pope was so much moved by Newton's accomplishments to write the famous epitaph.

“Nature and Nature's Laws lay hid in Night
God said "Let Newton be and all was Light".

I quote Newton

" I do not know what I may appear to the world but to myself I seem to have been only like a boy playing on the sea-shore and diverting myself in now and then finding a smooth pebble or a pettier shell than ordinary, while the great ocean of truth lay all undiscovered before me”.

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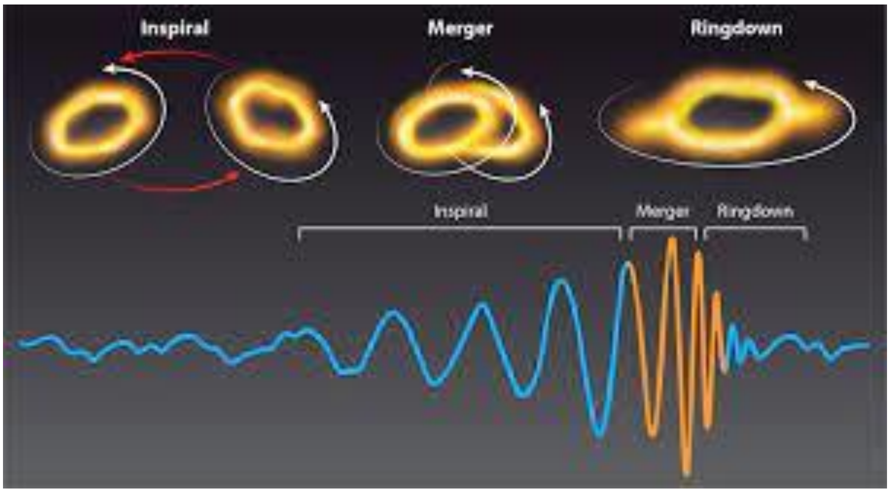
Inspiral
Merger
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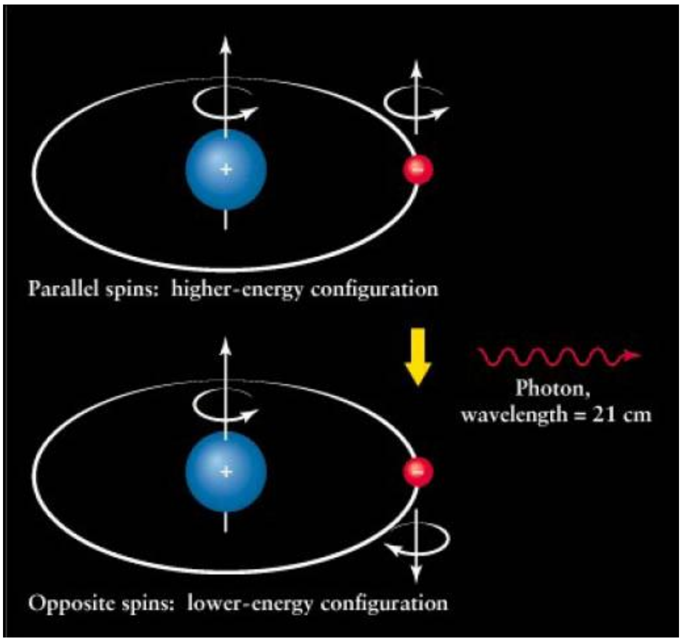
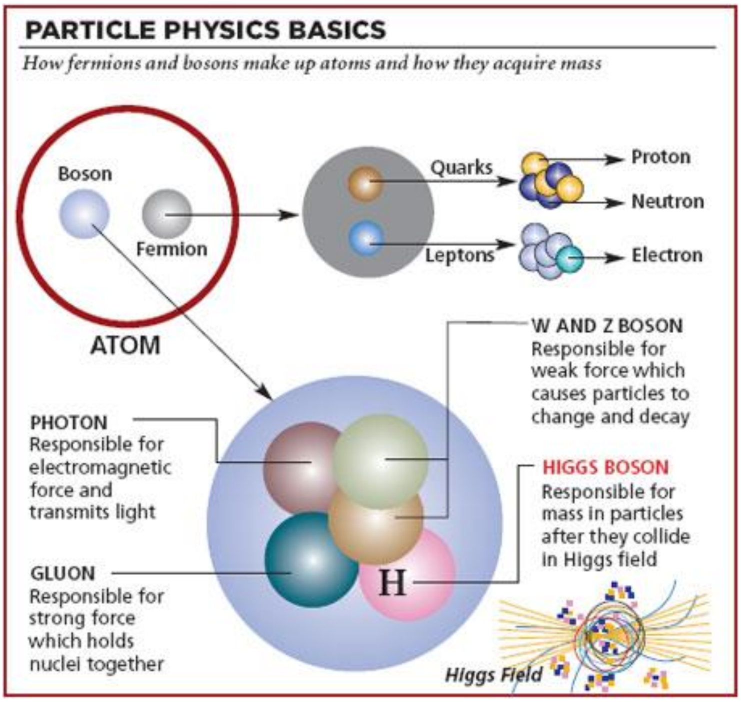

Parallel spins: higher-energy configuration
Photon,
wavelength = 21 cm
Opposite spins: lower-energy configuration


PARTICLE PHYSICS BASICS
How fermions and bosons make up atoms and how they acquire mass
Boson
Fermion
ATOM
Quarks
Leptons
Proton
Neutron
Electron
W AND Z BOSON
Responsible for weak force which causes particles to change and decay
PHOTON
Responsible for electromagnetic force and transmits light
HIGGS BOSON
Responsible for mass in particles after they collide in Higgs field
H
GLUON
Responsible for strong force which holds nuclei together
Higgs Field

PATHANI CHANDRA SEKHAR SAMANTA – THE INDIAN TYCHO BRAHE

Pathani Chandra Sekhar Sinha Samanta was an extraordinary and self-taught astronomer from India - much like Copernicus, Tycho Brahe and others. His ground-breaking work was based on naked-eye observations using simple instruments fabricated by himself and calculations that he did using traditional Indian mathematics. Unfortunately, Chandra Sekhar Samanta is not so well-known outside his home state of Odisha and beyond a handful of Indian astronomy enthusiasts. He lived and died in poverty even though his work was mentioned in scientific journals like *Nature* and *Knowledge* way back in 1899! Here is a brief account of the life and contributions of this great astronomer of nineteenth-century India.

Early life

Chandrasekhar Samanta, for short, was born on 13th December 1835 in Khandapada, Nayagarh district, Odisha. He was the son of Samanta Syamabandhu Sinha, the King of a princely state in modern-day Odisha. Soon after his birth, he was given away in adoption to a Muslim *fakir* to ward off the evil eye - a belief that was strongly prevalent at the time. In remembrance of the *fakir* and to ward off bad omens, the couple nicknamed their son 'Pathani'.

Samanta was a very bright boy with a keen interest in astronomy and mathematics. He was taught at home by his father, who also introduced him to the joys of night star-gazing. Later on, a kind local teacher gave him basic education in both Oriya and Sanskrit.T hat was the end of his schooling.

By the age of 15, he had become a self-learner, referring to the books available in the royal library. Samanta was a voracious reader and devoured classical treatises like *Lilavati, Bijaganita, Jyotisha, Siddhanta, Vyakarana* and *Kavya*. It was during this time that he pursued mathematics and traditional astronomy, and started matching predictions made by ancient Indian mathematician-astronomers such as Aryabhatta I, Varahamihira,Brahmagupta and Bhaskara – II and others with real observations of celestial objects in the night sky.He noticed several deviations from their predictions.

According to his family history written by his grandson, Raghunath Singh Samanta, in the book *Pathani Samanta Jeebani Darpana*, Samanta married Sita Devi, daughter of King Anugul, in 1857. It seems the bride's family refused the alliance on the couple's wedding day as Samanta didn't look princely enough! Apparently, he impressed the bride's family with hisflawless *sloka* recitation at the wedding venue.

Although traditional Indian astronomy then had turned more towards astrology, focusing more on future predictions based on planetary positions and the preparation of auspicious almanacks for rituals, Samanta focused his attention on the mathematical calculations and observational facts that went into these predictions. When he found discrepancies, he designed his instruments to measure the phenomena, using everyday materials such as wood and bamboo! Being in a remote and isolated place, he was unaware of telescopes and developments in astronomy in other places even within India.

Publication of Siddhanta Darpana

By the age of 23, Samanta was already making meticulous observations, noting discrepancies and making corrections. Over the next 11 years, he compiled his observations, research and calculations into a treatise titled *Siddhanta Darpana*, which took the form of a Sanskrit verse written in the Odiya script on palm leaves!

Although his treatise was completed in 1869, it took another 30 years before it was published in Devanagari script, on paper, thanks to the efforts of Mahesh Chandra Nyayaratna, Principal of Sanskrit College in Calcutta, who introduced him to Prof.Joges Chandra Ray of Cuttack College in Cuttack, Odisha. It was Prof. Ray who undertook the daunting task of publishing *Siddhanta Darpana* in the Devanagari script in 1899, with financial support from two kings – the King of Athmallik and the King of Mayurbhanj.

The treatise had a 56-page English introduction by Prof. Ray, who used it to explain Samanta's scientific contributions. His efforts drew the attention of Western academic journals like *Nature* (Vol 59, March 1899) and *Knowledge* (Vol XXII, Jan-Dec, 1899), with high appreciation that catapulted Samanta into a league that included the likes of celebrated Danish astronomer Tycho Brahe (1546 – 1601) renowned for his accurate astronomical observations. Nature cited, *"Prof. Ray compares the author very properly to Tycho. But we should imagine him to be greater than Tycho" and Knowledge acknowledged, "The work is of importance and interest to us, westerners also. It demonstrates the degree of accuracy which was possible in astronomical observation before the invention of the telescope".* Thus, the extraordinary work was saved from being forever consigned to oblivion.

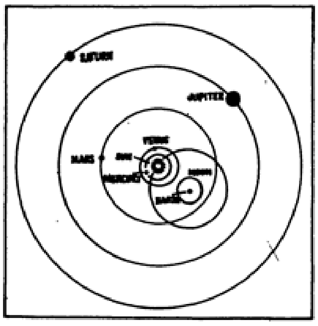
Although by 1835, Western knowledge systems were in place and optical telescopes had been trained at the sky, Samanta was unaware of Western doctrines and advanced observations. He worked in isolation in his rural, hilly abode in Odisha, using ancient Indian treatises as his beacons and constantly fixing discrepancies in them. In short, he believed in verifying the observations of his predecessors.

Samanta was unaware of the birth of modern astronomy ushered in by the great Galileo, followed by Kepler, Newton and Herschel. But what he did with the sources and texts he had at hand was unusual and extraordinary – he went through the ancient Indian treatises on astronomy meticulously, like Surya Siddhanta and others, matched their data with his observations and improved their accuracy. Then he wrote his own treatise, *Siddhanta Darpana*, whose level of accuracy is phenomenal compared to modern observations. The figures in *Siddhanta Darpana* are remarkably close to the currently accepted values.

Model of the Solar System

Incredibly, Samanta worked in tandem with Western astronomers in a later era without even knowing it. He attained comparable values without being aware of the development of Western astronomy and the great works of Copernicus, Tycho Brahe, Kepler, Galileo and many others and the strides it had over the last two centuries. He was also completely unaware of the big observatories that were built in India by Rajput ruler Jai Singh (1688 -1743) at Jaipur, Varanasi, Ujjain and other places.

This is clear from an innovative model of the solar system that he developed, where the inner and outer planets revolve around the sun but the earth remains stationary, with both the moon and the sun moving around the earth in different orbits.



Thus, his model of the solar system, shown in the figure to the left, was both heliocentric and geocentric, similar to the model proposed by Tycho Brahe, which challenged the long-held beliefs of the time. Furthermore, Samanta improvised his calculations by defining a mean longitude line (accounting for the tilt of the earth) and resetting the time scale.

The innovative planetary model independently proposed by Chandra Sekhar Samanta was very similar to the one proposed by the great astronomer, Tycho Brahe, and the astronomer from the Kerala school of astronomy- Nilakantha Somayaji.

Planetary Motion

The article published by Prof P C Naik and Prof L Satpathy in the *Bulletin of the Astronomical Society of India* (1998) shows the unbelievably meticulous work undertaken by Samanta. The following tables give the Sidereal periods of planets in days and the inclinations of the orbits of planets to the ecliptic according to Samanta and others.

Sidereal periods of planets in days

Planet	Surya Siddhanta	Siddhanta Siromani	Siddhanta Darpana	European value as in 1899	Modern value
Sun	365.25875	365.25843	365.25875	365.25637	365.25636
Moon	27.32167	27.32114	27.32167	27.32166	27.3216615
Mars	686.9975	686.9979	686.9857	686.9794	686.97982
Mercury	87.9585	87.9699	87.9701	87.9692	87.969256
Jupiter	4332.3206	4332.2408	4332.6278	4332.5848	4332.589
Venus	224.6985	224.9679	224.7023	224.7007	224.70080
Saturn	10765.773	10765.8152	10759.7605	10759.2197	10759.23
Moon's Nodes	6794.3948	6792.2535	6792.644	6793.270	6793.470

Inclination of the orbits of planets to the ecliptic

Planet	Surya Siddhanta	Siddhanta Siromani	Siddhanta Darpana	European value as in 1899	Modern value
	° ' "	° ' "	° ' "	° ' "	° ' "
Moon	4 30 –	4 30 –	5 09 –	5 08 48	5 08 33
Mars	1 30 –	1 50 –	1 51 –	1 51 2	1 50 59
Mercury	5 55 –	6 55 –	7 2 –	7 00 08	7 00 18
Jupiter	1 0 –	1 16 –	1 18 –	1 18 41	1 18 18
Venus	2 46 –	3 6 –	3 23 –	3 53 35	3 23 41
Saturn	2 0 –	2 40 –	2 29 –	2 29 40	2 29 10

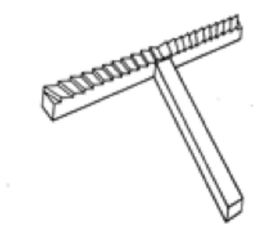
There are many more such tables showing a great degree of accuracy achieved by Pathani Samanta. He also pointed out that Bhaskara and others had approximated Pi as 22/7, whereas he used values 690/191 and 3927/1250 thus increasing accuracy. Samanta also devised a new method for finding the cube roots of numbers.

Observing Venus Transit

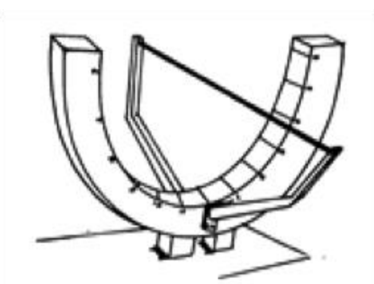
It is almost unbelievable that Samanta recorded the Transit of Venus (the passage of Venus across the sun as seen from the earth) in 1874, the first-ever observed from the Indian subcontinent. He recorded it in Sanskrit, oblivious to the excitement the phenomena had caused among astronomers in the West, who were looking at the transit through telescopes!

Working With Wood & Bamboo

The treatises Samanta was referring to had only limited clues to the observational devices they had used, so he decided to make his own measuring instruments made of locally available bamboo and wood. The following are two such instruments.



Mana Yantra for angle measurements



Chapa Yantra for time measurements

They used basic geometry and trigonometry to calculate distance, height and time. There are many local tales of Samanta measuring the height at which birds fly, finding the height of trees, persons using the length of shadows, calculating the distance and height of mountains from his fixed location using an instrument his Mana Yantra. To measure time, he used his own versions of the sun dial and improvised water clocks.

Awards & Recognitions

The Gajapati King of Puri awarded Chandra Sekhara Samanta the title “Harichandan Mahapatra” in 1870, and the famous Jagannath Temple of Puri still follows the calendar prescriptions proposed by him to observe its rituals.

The British government, which ruled India during Samanta’s lifetime, conferred upon him the title of “Mahamahopadhyay” in 1893 and awarded him a pension of Rs 50 per month for his contributions to astronomy after he correctly predicted the time and place of a solar eclipse that was visible only in Britain.

Final Days

Samanta continued to teach and drew students from far and wide but, all this while, he suffered from chronic health issues and insomnia. He passed away on 11th June 1904, after a bout of fever and infection.

Samanta’s native state Odisha has kept his legacy relevant by displaying his work in the state museum, naming the planetarium in Bhubaneswar after him; and dedicating educational institutions, scholarships and amateur astronomy clubs to his memory. His work is cited by astronomers and astrophysicists in India and abroad, and he has even been nicknamed ‘Indian Tycho’.

Most Indians are largely unaware of this great naked-eye astronomer and the phenomenal scientific contributions he made with only a few pieces of bamboo and wood – and the sheer power of his genius. He deserves to be celebrated just like Aryabhatta, Bhaskara and others - probably as the last torch bearer of the Indian traditional astronomy.

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New Applications of Bohr's Quantisation Rule

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Abstract

Here we present some new applications of the well-known Bohr's quantisation rule along with its modifications to deduce quantised energy levels of some simple systems. The values agree quite well with those of proper quantum mechanics.
Keywords: Bound states; Bohr's quantisation rule, Periodic systems.
PACS: 03.65.Ge,

1 Introduction

It is well-known how Niels Bohr in 1913 applied his, the then revolutionary quantum rule ($mvr = n\hbar$) to deduce the energy levels of the Hydrogen Atom[1]. Bohr's rule was successful in explaining the stability of the orbits overcoming the difficultie associated with classical explanations. Bohr's rule was later modified by Arnold Sommerfeld for elliptical orbits etc. Since then Bohr's rule apparently has not been applied to other systems as it was superseded by proper quantum mechanics developed by Schrödinger, Bohr and Heisenberg around 1926[2, 3]. In this article we apply Bohr's quantisation rule as well as it's suitable modifications to several periodic systems. We are able to deduce quantised energy levels in a remarkably simple way. The method presented has a pedagogical value too.

2 Simple harmonic oscillator

This is a system having Hamiltonian

$$H = \frac{p^2}{2m} + \frac{1}{2}Kx^2. \tag{1}$$

We can think about the linear motion as a projection of a uniform circular motion on one axis-say the $x-$axis. Thus, we can write

$$x = R\cos\omega t \tag{2}$$

where R is the amplitude and $\omega = \sqrt{\frac{K}{m}}$ being the uniform angular frequency[4]. Balancing the forces on m that is moving in a circular orbit of radius R, we have

$$m\omega^2 R = kR. \tag{3}$$

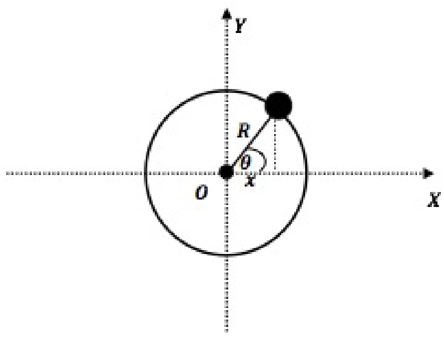

Figure 1: Projection of uniform circular motion on x axis.

Introducing Bohr's idea of quantisation for angular momentum, we can write

$$mvR = m\omega R^2 = n\hbar. \tag{4}$$

As $\omega^2 = \frac{K}{m}$, we get

$$R^2 = \frac{n\hbar}{\sqrt{Km}}. \tag{5}$$

Therefore, kinetic energy of the particle executing simple harmonic motion is

$$T = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2 R^2 = \frac{1}{2}n\hbar\omega$$

and the corresponding potential energy is

$$V = \frac{1}{2}KR^2 = \frac{1}{2}K\frac{n\hbar}{\sqrt{Km}} = \frac{1}{2}n\hbar\omega.$$

Thus, the total energy is

$$E = T + V = n\hbar\omega. \tag{6}$$

The exact value of energy of the simple harmonic oscillator obtained by solving Schrödinger equation is[5]

$$E = T + V = \left(n + \frac{1}{2}\right)\hbar\omega. \tag{7}$$

Replacing n by $\left(n + \frac{1}{2}\right)$ in equation (6) as one does in going from old quantum theory to modern quantum mechanics, Bohr's quantisation rule is able to give the exact values without solving Schrödinger's equation.

3 Charged particle in a uniform magnetic field

Let the axial magnetic field vary as

$$B = B_0.$$

Hence, we get a uniform circular motion of a particular radius R that is given by the equation:

$$\frac{mv^2}{R} = qvB_0 \tag{8}$$

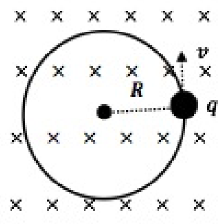

Figure 2: Charged particle in a uniform magnetic field

This has to be combined with the Bohr's rule

$$mvR = n\hbar.$$

We can write for the kinetic energy of the particle

$$T = \frac{1}{2}mv^2 = \frac{1}{2}qB\left(\frac{n\hbar}{m}\right) = \frac{1}{2}\hbar\omega_c. \tag{9}$$

Once again, this is a stationary system, i.e., a system in equilibrium. Hence, using equipartition theorem for equilibrium situations[6], on the average $T = V$.

$$\therefore E = T + V = 2T = n\hbar\omega_c, \tag{10}$$

where $\omega_c = \frac{qB}{m}$ is the cyclotron frequency[7].
If we replace n by $\left(n + \frac{1}{2}\right)$ and allow n to range over $0, 1, 2, \cdots$, Bohr's quantisation rule is able to reproduce the well-known Landau levels without the Schrödinger equation.

4 Simple harmonic oscillator with a modified method

We have the Hamiltonian

$$H = \frac{p^2}{2m} + \frac{1}{2}Kx^2.$$

Now for this one dimensional periodic system we modify the Bohr's rule to read

$$px = n\hbar, \tag{11}$$

and then find the stationary values of H to deduce the energy levels. Hence,

$$H = \frac{1}{2m}\left(\frac{n\hbar}{x}\right)^2 + \frac{1}{2}Kx^2. \tag{12}$$

Stationary state energies can be obtained by finding that x_0 for which

$$\left(\frac{dH}{dx}\right)_{x_0} = 0.$$

Thus we get

$$x_0^2 = \frac{n\hbar}{\sqrt{Km}}. \tag{13}$$

Putting the value of x_0 in equation (12), we get

$$H = \frac{1}{2}n\hbar\omega + \frac{1}{2}n\hbar\omega = n\hbar\omega. \tag{14}$$

These are the well-known harmonic oscillator energy levels[8], but for n in the place $\left(n + \frac{1}{2}\right)$ just as we have discussed earlier to pass from the old quantum theory to quantum mechanics.

5 Particle in a constant magnetic field by modified method

The Energy of a charged particle placed in an electromagnetic field is

$$E = \frac{p_1^2}{2m} + e\phi, \tag{15}$$

where $\vec{p}_1 = \vec{p} - \frac{e\vec{A}}{c}$ by using the minimal coupling rule.

$$\text{But} \quad \left(\tilde{\mathrm{p}} - \frac{\mathrm{e}\tilde{\mathrm{A}}}{\mathrm{c}}\right)^2 = \mathrm{p}^2 - \frac{\mathrm{e}}{\mathrm{c}}\left(\tilde{\mathrm{p}} \cdot \tilde{\mathrm{A}}\right) - \frac{\mathrm{e}}{\mathrm{c}}\left(\tilde{\mathrm{A}} \cdot \tilde{\mathrm{p}}\right) + \frac{\mathrm{e}^2}{\mathrm{c}^2}\mathrm{A}^2.$$

For a static magnetic field div$\vec{A} = 0$.

$$E = \left[\frac{p^2}{2m} - \frac{e}{mc}\left(\vec{A} \cdot \vec{p}\right) + \frac{e^2}{c^2}A^2 + e\phi\right]. \tag{16}$$

For uniform magnetic field (only H) along $z-$axis, we put $\phi = 0, H_x = H_y = 0, H_z = H$, we have the components of the vector potential:

$$A_x = -\frac{yH}{2}, A_y = \frac{xH}{2}\text{and } \ \mathrm{A_z} = 0 \tag{17}$$

$$\therefore \frac{e}{mc}\left(\vec{A} \cdot \vec{p}\right) = \frac{eH}{2mc}\frac{\hbar}{i}\left(x\frac{\partial}{\partial y} - y\frac{\partial}{\partial x}\right) = -\frac{eH}{2mc}L_z.$$

Putting these in equation (16),

$$E = \left[\frac{p^2}{2m} + \frac{e^2H^2}{8mc^2}\left(x^2 + y^2\right) + \frac{eH}{2mc}L_z\right]. \tag{18}$$

Now by using the modified Bohr's quantisation rule: $pr = n\hbar$ and putting $L_z = n\hbar$, we get

$$E = \left[\frac{n^2\hbar^2}{2mr^2} + \frac{e^2H^2}{8mc^2}r^2 + \frac{eH}{2mc}\left(n\hbar\right)\right]. \tag{19}$$

Now we minimise E in the equation (19) w.r.t 'r'. Let at $r = r_0$, $\left(\frac{\partial E}{\partial r}\right)_{r=r_0} = 0$, we get

$$r_0^2 = \frac{2n\hbar c}{eH}. \tag{20}$$

Putting equation (20) in equation (19), we get

$$E = \frac{eH}{mc}\left(n\hbar\right).$$

Taking $\Omega = \frac{eH}{mc}$, the cyclotron frequency

$$E = n\hbar\Omega. \tag{21}$$

Once again, replacing n by $\left(n + \frac{1}{2}\right)$,

$$E = \left(n + \frac{1}{2}\right)\hbar\Omega. \tag{22}$$

The eigenenergies thus obtained are exactly same as well-known Landau levels obtained by solving the Schrödinger equation[9].

Similar calculations can be done to verify the validity of the modified method for other higher order anharmonic oscillators.

6 Results and Discussion

Bohr's quantisation rule and its modification that is suggested here can be employed to deduce quantised energy levels of simple periodic physical systems without going through the elaborate steps of the standard quantum mechanics. The method suggested here can be used as a first step to get the energy levels quickly prior to solving the appropriate Schrödinger equation. More complicated systems such as molecular vibrations, coupled oscillators etc. lead to energy eigenvalue equations that may be solved numerically. Further, one can extend this method to the quantum mechanical systems possessing relativistic speeds using appropriate Hamiltonian. The method also has a pedagogical value in understanding periodic systems.

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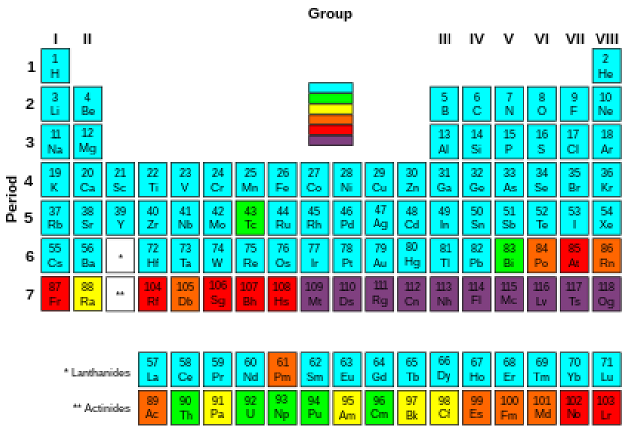

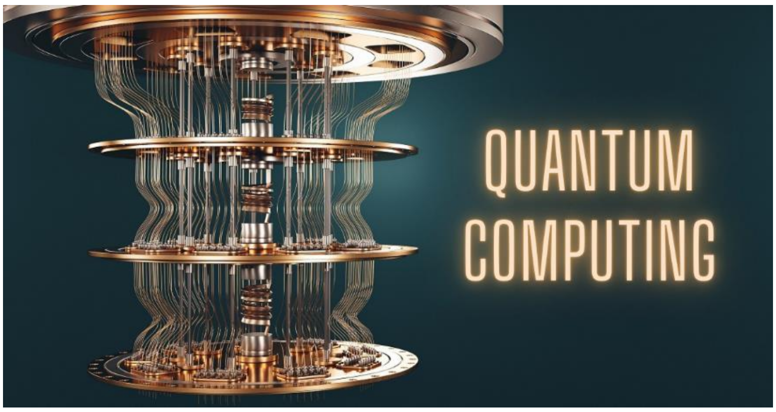

ACTIVITIES OF KPA DURING 1NOV '23 TO 31 JAN '24

1 Dr P Nagaraju delivered a talk on the "Science of Climate change" at SS Jain Subhodh P G College, Jaipur on Oct 11, 2023
2 Dr B A Kagali and Dr P Nagaraju demonstrated a few experiments to the students of Govt P U College, T Dasarahalli, Bengaluru on November 18,2023(10 AM to 1 PM)
3 Dr B A Kagali and Dr P Nagaraju demonstrated a few experiments to the students of 10th Standard, Ganga International School, Nagasandra, Bengaluru on November 18, 2023 (2. PM to 4.30 PM)
4 Dr B A Kagali and Dr P Nagaraju demonstrated a few experiments to the students of Basaveshwara P U College, Vijayanagar, Bengaluru on December 01, 2023
5 Dr B A Kagali and Dr S Somasekara were the guests at the J B R Degree College, Hoovina Hadagali for special lecture series on December 6, 2023
6 Dr B A Kagali and Dr S Somasekara were the resource persons for interaction with High School students for Physics topics at Govt High School, Kunigal, Tumkur District on December 19, 2023, organized by Agastya International Federation
7 Dr P Nagaraju gave a talk on Expecting the Unknown (Experiment at CERN) to the B.Sc., Students of Kuvempu Maha Vidyalaya Kengal, Channapattana on December 20, 2023
8 Dr S P Basavaraju delivered a talk on "The fascinating story of how Quantum Mechanics formulated" to the B.Sc., students of Govt Women's College, Chintamani on December 12, 2023
9 Dr S P Basavaraju delivered a talk on "The fascinating story of how Quantum Mechanics formulated" to the P U students of Manasa PU College, Besagarahalli, Maddur Taluk on December 19, 2023
10 Dr S P Basavaraju and Dr S Somasekara were the resource persons for the Interaction with High school students for Physics topics - Sapthagiri School, Halagur, Malavalli Taluk on Jan 09, 2024 - organized by Agastya International Federation
11 Dr S P Basavaraju and Dr S Somasekara were the resource persons for the Interaction with High school teachers for Physics topics on Jan 09, 2024 organized by Lions club, Halagur, Malavalli Taluk and Agastya International Federation on Jan 09,2024
12 Dr S Somasekara, Dr S P Basavaraju and Dr P Nagaraju were the resource persons for interaction with 10th Standard students of Govt High school Nelamangala, on Jan 10, 2024 organized by Agastya International Federation
13 Dr B S Srikanta delivered a talk on "Newton, Gravitation and Optics" in online Zoom platform organized by CreActive on December 2, 2023

14 Dr B S Srikanta delivered a talk on "Intellectual property Right – An insight" at Government Degree College, Malleswaram to the staff and students on Jan 02, 2024.

List of special on line (with zoom platform) lectures arranged in cooperation with Jnanadhara, Bengaluru

NO.	SPEAKER	TOPIC	DATE
1	Prof.N Uday Shankar	What hydrogen atoms tell us about the evolution of the universe, Part I	15.10.2023
2	Prof.N Uday Shankar	What hydrogen atoms tell us about the evolution of the universe, Part II	29.10.2023
3	Prof. Basavaraj Angadi	Recent Advances in Nanoscience and nanotechnology	05.11.2023
4.	Prof.A R Usha Devi	A tale of Quantum Computation	26.11.2023
5.	Prof.B Rudraswamy	Nuclear Reactions and the search for heavy elements	03.12.2023
6.	Prof.K B Vijaya Kumar	Fundamental forces and fundamental particles	10.12.2023
7.	Prof. B A Kagali	Variational principles in Physics	24.12.2023
8.	Sri.Sreenath Ratnakar	Bird's eye view of Space travel (in Kannada)	07.01.2024
9	Prof.B Eraiah	Advances in Glass Science and Technology	14.01.2024
10	Sri. Asitang Mishra	Introduction to Foundation Models and problem-Solving using Data Science	19.01.2024
11	Sri Sai Venkata Raman	Role of teachers in implementing scientific temper in high school students	28.01.2024