May 2017

APT TUNES

Academy of Physics Teachers, Kerala

APT Workshop : X-Ray Astronomy - Providence College, Kozhikode - 19-20 November 2016

APT Workshop : Virtual Observatory - SH College, Chalakudy - 16-17 July 2016

APT Workshop : Radiation - St Xavier's College, Aluva - 11-12 February 2017

MAY 2017

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Bulletin of

Academy of Physics Teachers, Kerala

Contents

Editorial

It is after a gap that the Academy of Physics Teachers, Kerala (APT) is coming up with another issue of APT Tunes. The Academy has been quite active in this period, organising a series of worthwhile programmes such as Talent Search Examination (TSE), workshop series that has crossed an impressive number, invited talks, training for Joint Admission Test for M.Sc. (JAM) etc and organising discussions on a variety of topics ranging from Physics Education to Science and Technology Policy.

One of the interesting development that has taken place recently is the confirmation of the existence of Gravitational Waves thus opening a new window to the study of our universe. It is heartening to note that this is a field for truly international collaboration where India and even Kerala finds a place. Effort to build a gravitational wave detector in India appears successful with in principle approval given by Govt. of India.

However, on the neutrino front there is bad news. Our efforts to construct an India -based Neutrino Observatory (INO) has met a road block in the form of a order from National Greens Tribunal. It was envisaged as an indigenous project that would have given us a definite edge in this field.

The APT, Kerala is in the forefront loading efforts for meaningful revision cf the Physics curricula for UG and PG programmes. In addition to discussions taken place along the sidelines of Physics workshops a lively debate is going on through social media. This is definitely going to yield good results in the long term. APT is sure to take a lead in changing the way physics is taught and learned in Kerala.

Our organisation is continuing the pursuit for excellence by organizing the annual event of Talent Search Examination throughout Kerala. The number of centres and candidates are showing a positive trend. Feedbacks from students and teachers suggest that this is a grand success and should definitely continue. This year we could make an attempt to help students trying JAM by organising mock online tests. Voluntary assistance from some of our young members helped us in that. We have good days ahead.

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Gravitational-wave Astronomy

A New Window to the Universe

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Editors Note :This article reproduced from 'Resonance' was written before the discovery of gravitational waves. Both of them were active members of the team that announced the discovery later.

We present a broad overview of the emerging field of gravitational-wave astronomy. Althoughgravitational waves have not been directly detected yet, the worldwide scientific community is engaged in an exciting search for these elusive waves. Once detected, they will open up a new observational window to the Universe.

Four hundred years after Galileo's telescope launched optical astronomy, a major revolution in astronomy using gravitational-wave telescopes is expected to occur in the very near future. Every new step in astronomy that allowed us to observe the Universe in a different wavelength of the electromagnetic spectrum has had immense and immediate impact on our science. While Galileo's observations challenged the prevalent worldview of the times and paved the way to the Enlightenment and the Scientific Revolution, the expansion of astronomy into other wavelengths of the electromagnetic spectrum - radio, microwave, infrared, ultraviolet, Xray, gamma-ray wavelengths - revolutionized our understanding of the Cosmos. Some of the most important observations include the discovery of new planets, new galaxies, extragalactic supernovae, quasars, pulsars, gamma-ray bursts, expansion of the Universe, cosmic microwave background, and evidence of astrophysical black holes.

The late 1980s witnessed the emergence of a new astronomy based on neutrino detectors. Neutrinos are subatomic particles produced by the decay of radioactive elements. Astrophysical neutrinos are typically produced in nuclear reactions that take place in the interior of stars, in contrast with electromagnetic waves, which are produced at the stellar surfaces. Hence, the observation of neutrinos enables us to probe the core of the astronomical source, thus complementing the electromagnetic observations. Neutrino detectors opened up the possibility of probing the Universe using observations other than that of electromagnetic waves. Scientists have now recognized the potential of 'multi-messenger' astronomy, in which different astronomical observations of the same phenomenon are combined to produce a more complete picture of the phenomenon.

1. Gravitational-Wave Astronomy

The existence of gravitational waves is one of the most intriguing predictions of the General Theory of Relativity proposed by Albert Einstein in 1915. General Relativity - the most accurate theory of gravity available - describes gravity as the curvature of the spacetime, produced by mass-energy concentrations in the spacetime. Whenever these mass concentrations change shape, they produce distortions in the spacetime geometry that propagate with the speed of light - called gravitational waves. The generation of gravitational waves is analogous to the generation of electromagnetic waves in a radio transmitter or a mobile phone. While changes in the electricfield produce electromagnetic waves, changes in the gravitational 'field' produce gravitational waves. According to General Relativity, gravitational waves also have two independent polarization states and propagate at the speed of light.

Although any accelerated motion of masses can produce gravitational waves, those produced by the motion of terrestrial sources are too weak to be detectable by any

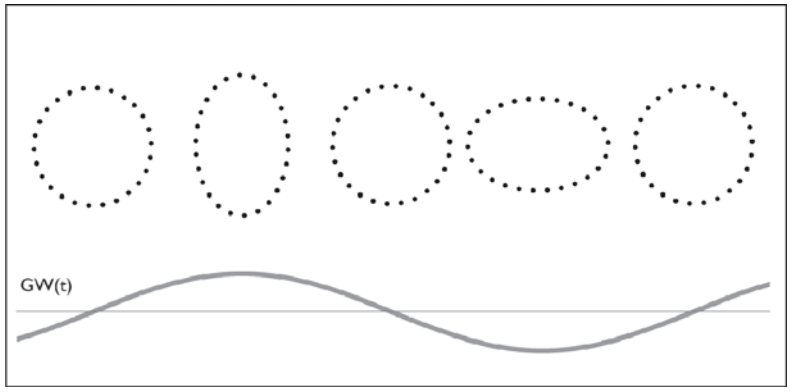
conceivable technology. Thus, unlike the case of electromagnetic waves, constructing a gravitationalwave 'generator' is not feasible in the foreseeable future. But a number of astronomical sources can produce gravitational waves that are detectable using the current cutting-edge technology. These include violent astrophysical phenomena such as colliding black holes, collapse of massive stars resulting in supernovae, rapidly rotating neutron stars, etc., and various energetic processes that might have happened in the early Universe. Unlike astronomical electromagnetic waves, which are produced by accelerating electrons or atoms and hence are of microscopic origin, gravitational waves are produced by coherent bulk motions of large amounts of mass-energy (except for the stochastic waves produced in the early Universe) and are of macroscopic origin. Thus, gravitational waves carry different information about their source, hence complementing the electromagnetic observations. Also, gravitational waves are the only means of directly observing certain sources, such as binaries of black holes, which are 'dark' in the electromagnetic spectrum. Furthermore, the interaction of gravitational waves with matter is extremely weak, which is a great advantage for astronomy. This means that these waves arrive at an observer nearly unaffected by any intervening matter, thus carrying 'uncorrupted'information about their sources.The weak coupling to matter also makes the detection of gravitational waves an enormous experimental challenge.

Although these elusive waves have not been directly detected yet, there are strong indirect evidences supporting their existence. General Relativity predicts that when two compact stars orbit a common center of mass, the gravitational waves would carry away the orbital energy and would cause the two stars to draw closer, and eventually to merge with each other. More than 30 years of radio observations of the binary pulsar system PSR B1913+16 showed that the decay of its orbital period agrees precisely with the prediction of General Relativity. (A pulsar is a rotating neutron star that emits a beam of electromagnetic radiation, so that observers from any fixed direction will see highly regular pulses). Russell Hulse and Joseph Taylor were awarded the Nobel Prize in 1993 for their discovery of this binary. In later years, more such binaries have been discovered, which further confirmed the prediction of General Relativity. Neutron stars and black holes are highly dense objects: A neutron star with mass equal to that of the Sun will have a radius of around 15 km, while a black hole with the same mass will have a radius of 3 km (recall that the Sun's radius is around 700,000 km). In a neutron star, matter takes exotic forms, which is a major puzzle for modern nuclear physics. In black holes, the matter is converted into an extreme form of spacetime curvature, such that a black hole is completely described by its mass, angular momentum and electric charge (popularly described as 'black holes have no hair!'). The merger of such compact objects are among the most energetic events in the Universe, where a small percentage of the mass of the objects is converted into gravitational energy according to Einstein's famous formula $E = mc^2$. For example, the energy released by the merger of two solar-mass black holes ($\sim 10^{46}$ J) is several hundred times larger than the electromagnetic energy released by the Sun over its entire lifetime! In the final stages of the coalescence of stellar-mass-black-hole/neutron-star binaries, the orbital frequency sweeps from around 10 Hz to a few kHz, which is the frequency band of audio signals that the human ear is sensitive to. Since the frequency of the emitted gravitational waves is twice the orbital frequency, it is possible to convert such signals into audio signals and 'listen' to them. In this sense, gravitational-wave astronomy is like 'listening' to the Universe. By decoding the emitted gravitational-wave signal, it is possible to extract the physical properties of the source, such as the component masses, spins, distance and energetics.

Gravitational-wave science holds the potential to address some of the key questions in fundamental physics, astrophysics and cosmology. For instance, the observed expansion rate of the Universe is inconsistent with the prediction of General Relativity based upon the mass-energy content of the Universe inferred from electromagnetic observations. This means that either General Relativity needs to be modified at large scales or that the

Universe contains enormous amount of mass-energy that is not visible in electromagnetic observations, termed 'dark energy'. Combined gravitational-wave and electromagnetic observations can be used to map the expansion history of the Universe, which is crucial in understanding the nature of dark energy. Gravitational-wave observations will also facilitate unique precision tests of General Relativity.

Gravitational waves from the merger of binaries involving neutron stars will carry information about the internal structure of the neutron star, and might reveal the central engine of certain types of gamma-ray bursts. (Although gamma-ray bursts are the brightest astronomical events in the



electromagnetic spectrum, not much is known about their central engines). In the case of a small compact object inspiralling into a much larger black hole, a 'map' of the spacetime geometry around the larger object will be encoded in the gravitational wave signal. Decoding the signal will enable us to infer the nature of the massive object, and to test whether it is indeed a black hole as described by General Relativity. Gravitational-wave signals from core-collapse supernovae will provide valuable information on the internal processes that take place during the explosion. Detecting the stochastic background of cosmic gravitational waves can help us to trace the Universe back to a time when it was as young as 10^{-30} seconds, which can be probed by no other astrophysical means.

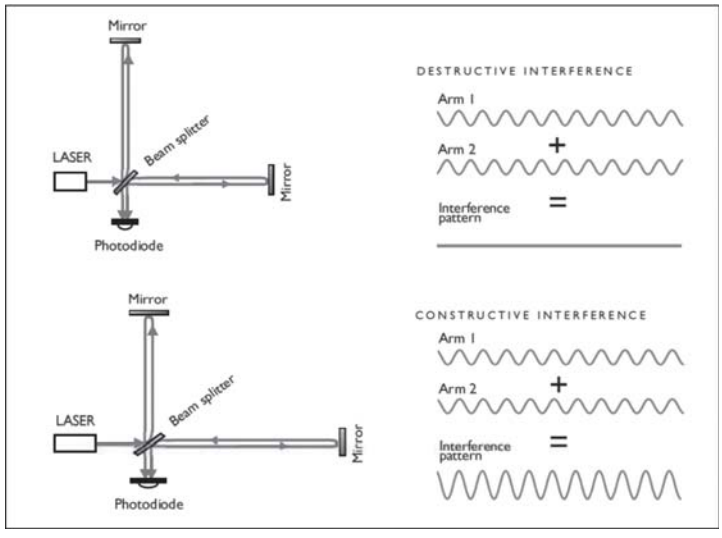
2. Detection of Gravitational Waves: A Major Experimental Challenge

When gravitational waves pass through the Earth, they distort the geometry of the spacetime. Observing the tiny distortions in the spacetime geometry is the key to the detection of gravitational waves. For example, assume that we arrange a ring of 'test masses' in a perfect circle. If a gravitational wave passes perpendicular to the plane of the circle, the spacetime will get distorted in such a way that the circle will get deformed into ellipses (see Figure 1). But, even if produced by some of the most energetic events in the Universe, the spacetime distortions produced by gravitational waves on the Earth is extremely small. For example, a core-collapse supernova in our own galaxy will produce a deformation of the order of a billionth of a trillionth (10^{-22} - 10^{-20}) of the radius of the circle!

Laser interferometry provides a precise way of measuring such small deformations. In a laser interferometer, a coherent laser beam is split by a beam splitter and sent in two orthogonal directions. These beams are reflected back by two mirrors, which are in turn recombined to produce an interference pattern. Gravitational waves induce a relative length change between the two orthogonal arms of an interferometer, which produces a change in the interference pattern.

Since the relative length change produced by a gravitational wave is proportional to the length of the arm, the longer the arm of an interferometer, the more sensitive it is. Thus, modern gravitational-wave telescopes are interferometers with arms several kilometers long. (In order to further increase the round-trip time, the light is reflected back and forth many times in each arm by creating resonant cavities). The LIGO (Laser Interferometer Gravitational-Wave Observatory) observatories in USA consist of two interferometers with 4 km arms. The French-Italian Virgo observatory has 3 km arms, while the British-German GEO600 detector has 600 m long arms and the Japanese TAMA300 detector has 300 m arms. These interferometers aim to detect gravitational waves in the frequency band of ~ 10 Hz to 10 kHz.

Almost all these detectors have achieved the design sensitivity goal of their initial configurations, and have conducted several long data-taking runs. Although a direct detection of gravitational waves is yet to be



made, the non-detection is consistent with the astrophysical expectations of the event rates (coalescence rates of compact binaries, galactic supernova rates, etc.) within the volume of the Universe accessible to the initial detectors. Several astrophysically interesting upper limits have been already derived based on this data. Advanced configurations of these observatories will be operational by 2015 with a factor-of-ten improvement in the sensitivity as compared to their initial configurations. Advanced ground-based detectors are expected to observe gravitational-wave signals at monthly or even weekly rates. A space-based antenna called LISA is also expected to be operational by the next decade, and a third generation ground-based interferometer called Einstein Telescope is being designed in Europe. These advanced detectors will provide powerful tools for precision cosmology, astronomy and strong-field tests of gravity.

Indeed, laser interferometry is not the only way of detecting gravitational waves. The experimental effort for this was pioneered by the American physicist Joseph Weber using resonant-bar detectors. The idea behind these detectors is that as a gravitational wave passes through an object, it will get deformed. If the object is vibrating at a characteristic resonance, then the deformation will appear as a deviation from its resonant ringing. Several resonant-bar detectors are operational around the world, although with lower sensitivity and bandwidth compared to interferometers. Another promising way of detecting gravitational waves in the very-low frequency band (10^{-9} - 10^{-6} Hz) is by using pulsar-timing arrays. The gravitational waves distort the spacetime when they pass through the Earth resulting in a correlated delay in the arrival times of the pulses from several pulsars. Millisecond pulsars (pulsars with rotational periods of a few milliseconds) provide a set of accurate 'reference clocks' which can be used to track such deformations. Several arrays of radio telescopes in Australia, Europe and North America are searching for gravitational waves in this frequency band. Also, experiments such as the recently launched Planck satellite will seek to detect ultra-low-frequency ($\sim 10^{-16}$ Hz) gravitational waves produced in the early Universe through their imprint on the polarization of the cosmic microwave background radiation.

3. Indian Participation

Interferometric gravitational-wave detectors are nearly omni-directional instruments. Thus, it is difficult to point the gravitational-wave detectors to a particular location in the sky or to identify the sky-location of a source from a single-detector observation. The skylocalization of the source is achieved by combining data from multiple detectors located at different geographical locations (similar to radio astronomy). Thus, it is important to have a worldwide detector network - both from the point of establishing confidence in our first detections, as well as exploring exciting new astrophysics from these sources. Several studies have pointed out that the optimal location for another detector to augment the sensitivity of the current global network is in the Indian Ocean region, with Australia and India as two potential choices.

The LIGO laboratory is currently investigating the possibility of installing a third Advanced LIGO detector in Australia or India with considerable international participation. This presents Indian science an excellent opportunity to launch a major initiative in a promising experimental research frontier well in time before it has obviously blossomed. The Indian researchers working in the field have formed a scientific consortium, called the Indian Initiative in Gravitational-wave Observations (IndIGO). The consortium now includes ten premier Indian institutions and about 30 researchers from India and abroad. The IndIGO collaboration aims to bring about a significant Indian contribution in building a gravitational-wave observatory in the Asia-Pacific region as a part of the global network. To support the research and development connected with this endeavour, a research group at the Tata Institute of Fundamental Research in Mumbai is currently building a 3-meter scale advanced interferometer prototype. The prototype will provide an active research and development platform for experimental gravitational-wave research in India.

With the ongoing upgrades of the ground-based interferometers, we are on the eve of a new era in astronomy. Direct, routine observations of gravitational waves expected by the middle of this decade will revolutionize our understanding of the Cosmos. Future observatories like Einstein Telescope and LISA will take gravitationalwave astronomy to the forefront of precision astronomy.

There are plenty of ongoing activities in India contributing to the development of various aspects of gravitationalwave astronomy, thus providing the motivated young minds a unique opportunity to be part of this emerging and exciting research frontier.

Courtesy : Resonance

Phosphosphorene from Black Phosphorous; Replacement for Graphene?

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As now the researchers are talking a lot about Graphene, something new and interesting news are coming from a group of scientist who derived Phosphorene from Black Phosphorous which may become a substitute for Graphene. Graphene is a single tightly packed layer of carbon atoms that are bonded together in a hexagonal honey comb lattice. It is the thinnest compound known to man at one atom thick, the lightest material known, the strongest compound discovered than steel and with a tensile stiffness of 15,0000,000 psi, the best conductor of heat at room temperature and also the best conductor of electricity known. It is also a light absorber and suitable for use in spin transport.

Because of all these peculiar properties and ease of availability of carbon, researchers are in a hurry to find applications for Graphene to make revolutionary development in electronics and technology. But Graphene lacks a natural band gap which adversely affect its usefulness as a replacement for the semiconductor switches in computer circuit as we know that desirable candidate for digital transistor application should possess a high charge carrier mobility for fast operation, a high on/off ratio(requiring a moderate band gap larger than 0.4 eV) for effective switching, high conductivity for low power consumption. Even though Graphene possesses exceptionally high carrier mobility (200,000 $cm^2V^{-1}s^{-1}$), its semi-metallic nature makes it not able to achieve a low off-state current or a high on/off ratio, which limits its use as a digital logic device.

The introduction of Phosphorene to the 2D family is now becoming a hot topic among the researchers as its novel properties are fascinating. Phosphorene is the single – or few-layer form of Black Phosphorous which was discovered recently as a two dimensional layered material holding great promise for application in electronics and optoelectronics. Phosphorene distinguishes itself from other 2D layered materials by its unique structural characteristics as it has a puckered structure along the armchair direction, but it appears as a bilayer configuration along the zigzag direction. This structural anisotropy can be seen in its local bonding configurations. Unlike the indirect-to-direct band gap transition in TMDCs, the band topology remains the same with changing thickness i.e. all few –layered Phosphorene samples are direct semiconductors with the band minimum at the gamma point. The thickness independent band topology of Phosphorene is important for its potential photonics and optoelectronics applications. The gap value (0.3-2 eV) is typically smaller than those of the transition-metal dichalcongenide compounds (1.1-2.5 eV), but larger than semi-metallic Graphene, enabling Phosphorene to

possess a moderate on/off ratio (10^4 -10^5) while preserving a sufficiently large carrier mobility (around 1000 cm^2/V.S) suitable for many applications. Graphene has extremely high mobility, but its lack of an intrinsic band gap renders it impractical in FET application due to a small on/off ratio.

	Phosphorene	Graphene
Band Gap	0.3-2 eV [9]	0 [3]
Effective Mass	0.146 m_e (1.246) [19]	~0 [3]
Carrier Mobility	~1000 $cm^2.V^{-1}.s^{-1}$ [9]	200,000 $cm^2.V^{-1}.s^{-1}$ [87]
On/Off Ratio	10^3-10^5 [9-10]	~5.5-44 [88]
Thermal Conductance	36 (110) W/m-K [23]	2000-5000 W/m-K [83]
ZT	1-2.5 [24]	~0 [83]
Critical Strain	27% (30%) [25]	19.4-34% [89]
Young's Modulus	44 (166) GPa [25]	1 TPa [89]
Poisson's Ratio	0.4 (0.93) [27]	0.186 [89]

First-principle calculations reveal that monolayer Phosphorene can withstand a tensile stress and strain up to 10 N/m and 30% respectively. The band gap experiences a direct –indirect-direct transition when axial strain is applied. Calculations also predict a semiconductor-to-metal transition in bilayer Phosphorene under a normal compressive strain; however 2D materials tend to crumple under compressive deformation which cast doubt on the simulations that omitted such a possibility. The band gap is shown to be robust against compressive strains along the zigzag direction due to ripple deformation.

Phosphorene displays promising potential for thermoelectric applications. Thermoelectric devices rely in the Seebeck effect to convert heat flow into electricity and the Seebeck coefficient is proportional to the ratio of a device's electrical conductance to its thermal conductance. The overall device efficiency is measured by the thermoelectric figure of merit, ZT. To maximize ZT value, it is desirable to achieve simultaneously a high electrical conductance and a low thermal conductance, which presents formidable challenge since the electrical and thermal transport are positively correlated in most materials. The intrinsic anisotropy of lattice and electronic properties in Phosphorene offers a unique solution to this challenge. Such a favorable alignment of a good electrical conductance and poor thermal conductance would significantly enhance Phosphorene's thermoelectric performance. Phosphorene based devices can reach an energy conversion efficiency of 15-20%, meeting the criterion for commercial use. Hence, Phosphorene is an outstanding candidate material for thermoelectric devices. Even though Graphene shows a very large Seebeck coefficient value, it's very high thermal conductivity renders the ZT value of Graphene impractically small.Phosphorene demonstrates superior flexibility while its Young's modulus is considerably smaller than those of graphene. It also exhibits an anisotropic Poisson's ratio and its value along the zigzag direction is 2-4 times larger than that in the armchair direction.Phosphorene has been predicted to become superconducting with an estimated transition temperature of 3-16 K driven by doping and biaxial strain. It is also suggested to be superior gas sensor due to its adsorption sensitive surface and direction selective I-V response.

As a summary we can say that Phosphorene's comprehensive range of desirable physical parameters for device applications, makes it a more favorable choice on balance than graphene, which shows superior properties in some regards but lack the necessary characteristics in others. Also Phosphorene is an outstanding member among the growing family of 2D layered materials which is giving a wide opportunity to the research world to explore its application in electronics, optoelectronic and photovoltaics and to find new simple and efficient methods for synthesizing Phosphorene commercially.

Reference:

- Semiconductors: Phosphorene excites materials scientists, *Physicists look past graphene for atom-thick layers that could be switches in circuits,* by Eugenie Samuel Reich.
- Phosphorene: Fabrication, Properties and Applications, Liangzhi Kou*, Changfeng Chen and Sean C. Smith

Stratosphere-Troposphere Wind Profiler Radar at CUSAT

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CUSAT

Overview: The Cochin University of Science and Technology (CUSAT) has recently installed the most sophisticated and indigenously developed Stratosphere-Troposphere (ST) radar being operated at 205 MHz frequency. Besides being the first radar in the World operating at this frequency, it is also the first wind profiler radar in the near equatorial site set up primarily to study the characteristics of Indian summer monsoon right at its Gateway at Cochin. This radar promises to be a cost effective and high precision technology capable of monitoring the weather under all weather conditions. The data from this radar is envisioned to add a new dimension to studies on monsoon dynamics. Design, development, fabrication, installation and testing of this state-of-the-art system are achieved by the technical and scientific supervision of CUSAT Scientists and Engineers. TheRadar has been installed in the campus of Advanced Centre for Atmospheric Radar Research (ACARR) under CUSAT. The ST radar bears 619 three element Yagi-Uda antennae capable of probing atmosphere from 315m to 20 km. The technical aspects and initial results of the prototype Radar were published in peer reviewed scientific journals.

The 619 element antenna arrangement of ST radar

Uniqueness: The conventional wind profiler Radars operate at 50 MHz, 400 MHz and 1000 MHz frequency bands. Nevertheless, they have certain demerits in terms of entire height coverage, vertical resolution, noise-to-signal ratio, high costs etc. However, the Cochin Radar operating at 205 MHz (which was typically allocated for TV and Radio broadcasting) has got several advantages over those conventional radars. The noise from external sources such as galactic or cosmic noise is an important issue for radars operating in the frequency range of 50-1000 MHz. Compared to the 50 MHz radar, the 205 MHz radar is less affected by cosmic noise, and hence the accuracy of its measurements would be much better.

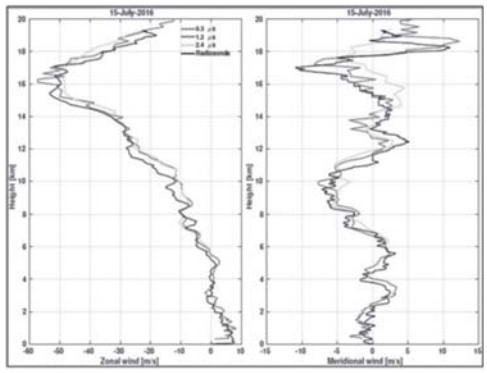
Moreover, radars operating in UHF ranges are known to get saturated under rainy conditions, while such issues do not affect radar at a frequency of 205 MHz. In fact, it is a trade-off between the 50 and 400 MHz radars in terms of galactic noise, cost effectiveness, physical size of antenna, better vertical resolution, and height

coverage, especially when the tropical tropopause height could go beyond 15 km. This active phased array ST Radar is supposed to be the first of its kind in the world at this frequency and having a height coverage right from 315 m to about 20 km with high vertical resolution.As a result, in a high-level meeting recently held under the auspices of NITI Aayog, Govt. of India, it is decided to showcase the Cochin Radar under the Prime Minister's'Make in India' Program.

Applications: The ST Radar has immense applications in the study of following the topics:

- *Characteristics of Monsoon circulation during itsonset, break and active and phases*
- *Inter-annual and Intra-seasonal variability of Indian summer monsoon*
- *Extreme weather events, severe droughts, landslides and floods*
- *Thunderstorm activity, Lightning, land and sea breezes*
- *Atmospheric Turbulence, wave activity, Civil aviation, Helicopter operations*
- *Ionospheric variability, space weather events, Radio Astronomy*
- *Climate change and variability, Stratosphere Troposphere exchange*

Agriculture, Plantation and Crop yields, Hydro-Electrical Power Generation, and Planning, etc..



Comparison of radar and radiosonde wind profiles for 15th July 2016

A Comparison of wind profilesof radar versus GPS radiosonde

The radar wind profiles have been validated using co-located GPS wind measurements launched from the radar's location. The radar wind profiles are in excellent agreement with the radiosonde wind measurements for the altitude range of 315 m to 20 km. The radar was operated under three different coded modes having baud rates of 0.3, 1.2 and 2.4 μs and then compared against radiosonde measurements.

Dr V K Saraswath with ST Radar Project Team at Cochin

Digital Hyperspectral Imaging for safety, security and art conservation

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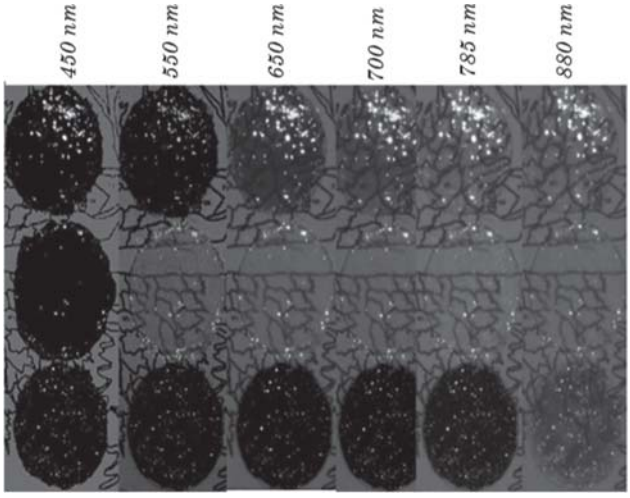
Hyperspectral imaging (HSI) is an intensive data-processing method combining imaging and spectroscopy to survey a scene and extract detailed information. HSI systems can collect spectral and spatial information from ultraviolet to longwave IR (LWIR) wavelengths. This creates a "data cube" containing information about the properties of a target at hundreds to thousands of narrow wavelength bands within the system's field of view. The number of pixels varies depending on the sensor of the instrument. For each pixel, the system obtains and plots a brightness value at each wavelength to create a continuous spectrum for the image cell. "If a picture is worth a thousand words, a hyperspectral image is worth almost 1,000 pictures."

Scientists can cross-check the obtained spectra with known, unique spectral fingerprints to detect, characterize and identify chemical compositions, materials, activities or events.

Originally designed for top-secret military satellites and surveillance in the 1980s, hyperspectral technology has been limited by its high cost and the difficulty of processing the huge amounts of data it produces. But recent computing advances and improvements in data acquisition and analysis have extended HSI's benefits to countless applications, from astronomy to weather forecasting. And many of these new applications—such as food inspection, pathogen detection, airport security, law enforcement and oil and gas pipeline inspection—are all about security and safety. Recently, Amazon received approval to fly drones with ultra compact HSI system, in testing of new unmanned delivery methods.

Compact HSI systems can be carried in drones for aerial surveillance and precision agriculture.

Applications of spectral imaging with limited spectral bands instead of numerous bands in cultural heritage preservation sector are very interesting. It has many advantages over several traditional techniques. Multi-spectral imaging system for analysis of artistic painting works can serve as a non-destructive tool, for acquiring data, which cannot be acquired by visual inspection



alone and which is highly relevant to art preservation, authentication and restoration.

Art 'detectives' searching for a long-lost Leonardo masterpiece have found traces of paint in a palazzo in Florence which match with that used by the Renaissance genius for the "Mona Lisa". This is a black pigment made up of an unusual combination of manganese and iron and corresponds exactly to paint used not only in the "Mona Lisa" but also in another celebrated Da Vinci work, "St John the Baptist". Researchers claim that this discovery is the first definitive proof that the Leonardo work lies hidden beneath a huge battle scene subsequently painted in the same spot by the artist Giorgio Vasari.

The bands residing in the visible domain provide an accurate measurement of the color information which can be used for true colour visualization but also for conservational and archival purposes by making a digital library. This investigates the possibility of re-documentation, long term conservation and revival. Secondly, inspection of the multispectral imagery by art experts and art conservators has shown that combining the information present in the spectral bands residing outside the visible domain can lead to a richer analysis of paintings. The infrared bands give us a great deal of information about restorations and distinction of vague underdrawings. The UV spectral band, on the other hand, allows for a thorough study of the top layer. This may be the varnish covering the paint, which is believed to be added afterwards.

Figure shows the monochromatic (not RGB image) spectral image of three coloured circles (Blue-Yellow-Red), painted on a canvas. This was captured by the MSI system at Maharaja's College, Ernakulam.

Monochromatic spectral images above 650 nm shows an increase in the reflectivity of the paint layer. Note that the hidden underdrawings on the canvas are clearly seen, at higher wavelength bands.

It is is believed that even the most advanced colour camera can only give an approximate colour reproduction of the frame. Another aspect of MSI is to assist in the research for the true colour reproduction by photography. HSI/MSI is the best digital support to conservators of cultural heritage sector. The possibilities and challenges in this emerging research area is yet to be explored in our country.

Indian Neutrino Observatory – A feasible underground nuclear detector for precision determination of neutrino oscillation parameters.

Dr. Jaiby Joseph
K E College, Mannanam

Editors Note :Dr. Jaiby Joseph is and experimental nuclear physicist and holds her Ph.D from Kent State University, Ohio, USA. She has worked with the STAR collaboration in analyzing data from Relativistic Heavy Ion Collider (RHIC). At present she is collaborating with Indian Neutrino Observatory (INO) team.

Abstract

The Indian effort in solving the question of neutrino mass hierarchy by setting a neutrino experiment has been on going– the **I**ndian **N**eutrino **O**bservatory (**INO**). The INO detector will be used for a precise determination of atmospheric mixing parameters and neutrino mass hierarchy with more precision than what has been possible before. The atmospheric muon neutrinos while passing through the iron plates of the INO-ICAL detector decay via the weak interaction process and are the primary signals in the study of neutrinos here.

A measurement of muons in the detector indicates the atmospheric neutrino content. Current studies aims to measure oscillation sensitivity using Monte Carlo simulation, using realistic detector resolutions and efficiencies of the INO-ICAL experiment.

Neutrinos and why detect them

Neutrinos are tiny, elementary particles, which interact with matter via the weak force. They are uncharged and they rarely interact with matter. This makes matter almost transparent to them. The Sun and other stars produce neutrinos copiously (about two hundred trillion trilliontrillion of them every second!) and they reach earth uninterrupted. If you hold your hand towards the sunlight for one second, about a billion neutrinos from the sun will pass through it, this is because they are a byproduct of nuclear fusion from the sun. Supernovae explosions produce 1000 times more neutrinos than the Sun produces in 10 billion years' life time! They are important to be studied for the understanding of the processes that are going on in the sun.

The neutrino was proposed by Wolfgang Pauli in 1930 and actually detected in 1956 by Reines and Cowan. It is now known that there are three types of neutrinos and their antiparticles and that they have a tiny mass. The mass of neutrinos is still not known with precision.Neutrinos exhibit a quantum mechanical phenomenon known as neutrino oscillation in which one type of neutrino oscillates into another as it propagates in space.

Neutrinos are the most numerous particles in the world, therefore even their tiny mass adds up to give large gravitational effects. Moreover the relic neutrinos (created at the beginning of the Universe) can give us pivotal information about the evolution of the Universe, in other words, they contain the blueprint of nature!

Charged current(CC) and Neutral current(NC) interactions

In CC interactions, the neutrino converts into the equivalent charged lepton and the experiment detects the charged lepton. The hadrons get absorbed in the material (rock or iron plates). NC interactions transfers energy and momentum to whatever it interacted with

and the neutrino remains a neutrino itself. We detect this energy transfer, either because the target recoils or because it breaks up. Charged-current interactions occur through the exchange of a $W^{\pm}$ particle, neutral-current through the exchange of a Z^0.

Muons generally come from three sources; (1) neutrino events producing muons through the interactions inside ICAL detector, which comes under the main studies of ICAL. These are mainly muon tracks. (2) cosmic ray muon events produced in the earth's atmosphere, directly interacting with ICAL (3) Upward-going muons, also known as rock muons, arise from the interactions of atmospheric neutrinos with the rock material surrounding the detector in the earth's crust. The rock muons provide an independent measurement of the oscillation parameters.

The magic of neutrino oscillations

Neutrino oscillation is a quantum mechanical phenomenon whereby a neutrino created with a specific lepton flavor can later be measured to have a different flavor. The probability of measuring a particular flavor for a neutrino varies periodically as it propagates through space. Neutrino oscillation is a simple consequence of its wave property. It arises from a mixture of the flavor and mass eigen states of neutrinos. That is, each of the three neutrinosare a different superposition of the three neutrino states with definite mass. Neutrinos are created in weak processes in their flavor eigen states. As neutrino propagates through space, the quantum mechanical phase of the three mass states advance at slightly different rates due to the slight difference in mass. This results in changing mixture of mass states as the neutrino travels. But a different mixture of mass states corresponds to a different mixture of flavor states. Thus the electron neutrino will be some mixture of electron, mu and tau neutrino after travelling some distance.

The neutrino mixing matrix (U_{PMNS}) can be parameterized in terms of three mixing angles θ_{12},θ_{13}, θ_{23} and a charge violating phase δ_{CP}. The frequencies of neutrino oscillations are governed by the two mass squared differences $\Delta m_{21}^2$and $\Delta m_{31}^2$where $\Delta m_{ij}^2 = m_i^2 - m_j^2$. Accelerator based, short and long baseline reactor neutrino experiments and atmospheric neutrino experiments all have so far reported the following data on neutrino oscillations:

Parameter	Best fit value
$\sin^2\theta_{12}$	0.307
$\sin^2\theta_{23}$	0.386
	0.392
$\sin^2\theta_{13}$	0.0241
	0.0244
Δm_{21}^2 (eV^2)	7.54×10^{-5}
Δm_{32}^2 (eV^2)	2.43×10^{-3} 2.42×10^{-3}

Table 1: Neutrino oscillation parameters so far reported by various experiments.

The INO Experiment

The experiment is located at West Body Hills in Theni district of TamilNadu. The detector is known as Iron CALorimeter (ICAL) weighing 50,000 tonnes of magnetized iron kept a kilometer underground. It has 140 layers of iron plates interleaved with 2.5 cm air gaps. These air gaps contains active detector elements. ICAL consists of three identical modules each of dimension 16 m × 16 m × 14.45 m. The active detector elements are about 30,000 glass Resistive Plate Chambers (RPC).

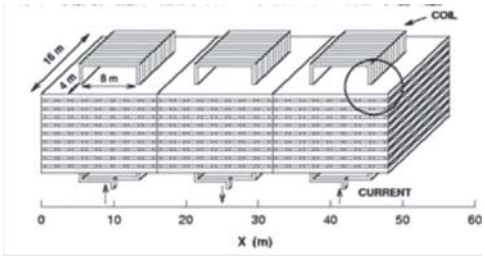


Fig.1: Layout of the detector modules of ICAL

The RPCs have good position and time resolution. The magnetic field is generated, by passing current through copper coils as shown in Fig.1. In each of the three modules, there is a central region where the field is highest and uniform, a side region where the field is 15% smaller and a peripheral region where the magnetic field changes in both direction and magnitude. Both peripheral and side regions are affected by the edge effects since both of them have partially contained events.

INO hosts the biggest electromagnet in the world. The main advantage of a magnetised iron calorimeter is its ability to distinguish μ^+ from μ^-, and hence to study ν_μ and $\bar{\nu}_\mu$ separately. The identification of μ^- from μ^+, is crucial in determining the oscillation parameters; Δm^2 and mass hierarchy precisely.

The probability for oscillation of neutrinos from one flavor to another depends on the source to detector distance and energies of neutrinos. To measure the oscillation parameters more precisely, it is important that the neutrino energy and its incoming direction be accurately measured for each event. We also need to know the flight direction (up versus down) of the muons

produced by the neutrinos with high efficiency. Measurement of track curvature with a known B-filed and the timing in successive detector layers can be used to achieve this. ICAL can measure both these.

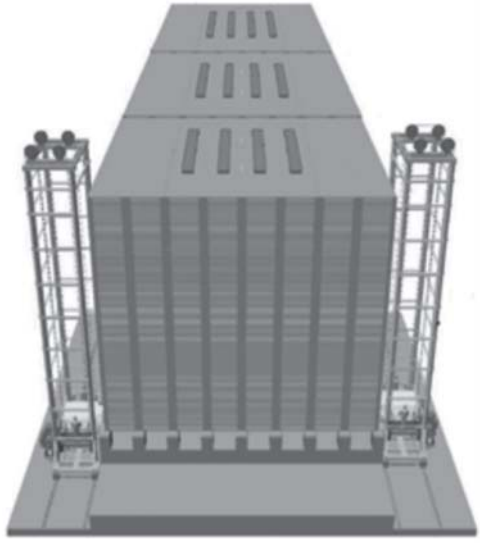


Fig.2 : Schematic of the INO- ICAL detector

The energy of the neutrino is the sum of the hadronic and muon energies for a charged current interaction. It is difficult to reconstruct the energy for individual hadrons. But the hit multiplicity of the charged particles distinct from the muon track can be used to estimate the total energy of the hadrons. The hadron momentum is estimated from the track length. Muon energy is measured either by its curvature in the B-filed or from the range of muons stopping in the detector.

Analysis using simulation data and Results

The complete simulation software has been built and running in the INO collaboration. The latest INO reconstruction software uses Genie[§] 2.6.8 as the event generator. This uses the HONDA flux with the 3D-flux information from INO site. In addition to the energy E_i and cosè$_i$ dependence, the HONDA flux at INO site has dependency on azimuthal angles also (divided into bins of 30°). There is observable variation in neutrino flux in azimuthal direction for neutrinos with energy well below 10GeV. For energies comparable to 10 GeV, a flat distribution of phi angle is seen. So inclusion of phi dependent flux information is absolutely necessary for the study of atmospheric neutrinos at INO. The following are some of the resolution plots obtained with simulated particles in the INO reconstruction environment.

Using the detector resolutions and efficiencies obtained from the INO collaboration from a full detector GEANT4 simulation data, the reach of the experiment for the measurement of atmospheric neutrino mixing parameters

($\sin^2\theta_{23}$ and $|\Delta m_{32}{}^2|$) are projected. These results correspond to a statistics of 10 years of ICAL exposure.

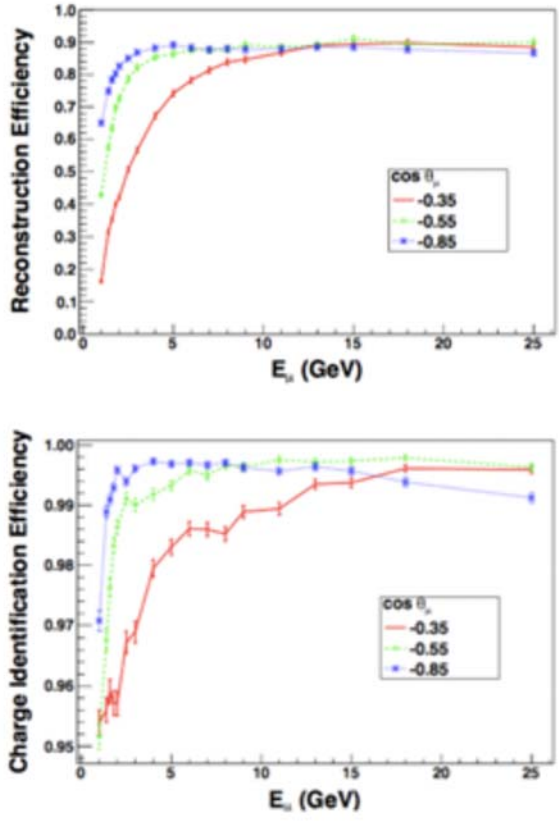


Fig.3 : Reconstruction efficiency (top) and charge identification efficiency (bottom) for muons.

The precision of ICAL on $\sin^2\theta_{23}$ in 10 years is expected to be comparable to what we currently have from Super Kamiokande (SK) experiment. In Fig. 4, the Δm_{32} values are shown for different confidence levels. The ICAL will not and cannot be competing with the SK, T2K and Nova experiments' precision but the ICAL data will give complementary information on these parameters which will significantly contribute to the improvement of precision of global fit.

[§]Genie is a neutrino event generator and it has several toolsto simulate complex experimental set ups.

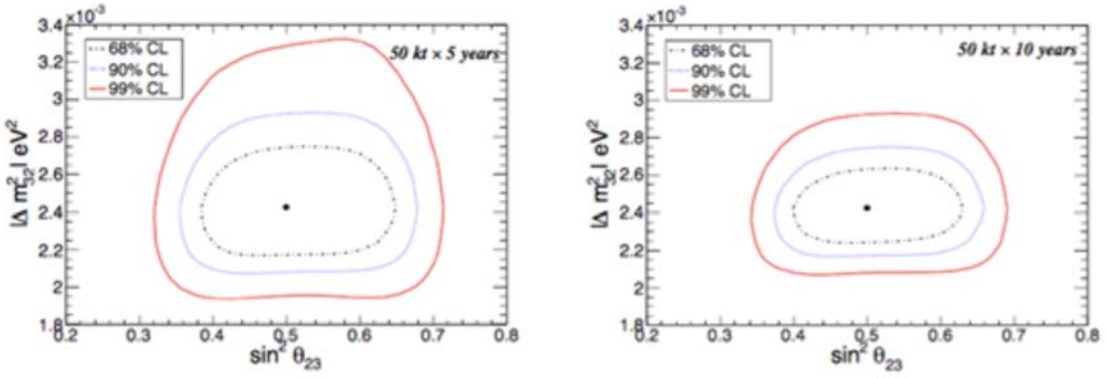


Fig.4 : Precision reach for 5 years of run (left) 10 years of run (right)

In addition to muon analysis, the hadrons associated with the charged current interaction of muon neutrinos can provide energy and angle information about the neutrinos. This can lead to improved sensitivity and better oscillation parameter calculation.

The Future

The procedural lapses on the part of experimental collaboration and assumptions about the project's agenda has made a project of this scale hard to bear fruit in India. Allegations such as neutrinos are radioactive particles and that INO will double up the storage of nuclear waste have damaged the collaboration's many years of outreach efforts. Any further delays could defeat the purpose of the project because similar projects elsewhere could undermine India's efforts.

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Proposed site for INO

LIGO-India

LIGO-India is a planned advanced gravitational-wave observatory to be located in India as part of the worldwide network. The project recently received the in-principle approval from the Indian government. LIGO-India is planned as a collaborative project between a consortium of Indian research institutions and the LIGO Laboratory in the USA, along with its international partners Australia, Germany and the UK.

What is LIGO India?

The Laser Interferometer Gravitational-wave Observatory (LIGO) project operates three gravitational-wave (GW) detectors. Two are at Hanford in the state of Washington, north-western USA, and one is at Livingston in Louisiana, south-eastern USA. Currently these observatories are being upgraded to their advanced configurations (called Advanced LIGO). The proposed LIGO-India project aims to move one Advanced LIGO detector from Hanford to India. LIGO-India project is envisaged as an international collaboration between the LIGO Laboratory and three lead institutions in the IndIGO consortium: Institute of Plasma Research (IPR) Gandhinagar, Inter University Centre for Astronomy and Astrophysics (IUCAA), Pune and Raja Ramanna Centre for Advanced Technology (RRCAT), Indore. LIGO lab would provide the complete design and all the key detector components. Indian scientists would provide the infrastructure to install the detector at a suitable site in India and would be responsible for commissioning it. The proposed observatory would be operated jointly by IndIGO and the LIGO-Lab and would form a single network along with the LIGO detectors in USA and Virgo in Italy.

Design: The proposed detector will be a Michelson Interferometer with Fabry-Perot enhanced arms of 4 km length and aims to detect differential changes in the arm-lengths as small as $10^{-23}Hz^{-1/2}$ in the frequency range between 30 to 800 Hz. The design would be identical to that of the Advanced LIGO detectors that are being commissioned in the USA

Scientific benefits

The scientific benefits of LIGO-India are enormous. Adding a new detector to the existing network will increase the expected event rates, and will boost the detection confidence of new sources (by increasing the sensitivity, sky coverage and duty cycle of the network). But the dramatic improvement from LIGO-India would come in the ability of localizing GW sources in the sky. Sky-location of the GW sources is computed by combining data from geographically separated detectors ('aperture synthesis'). Adding a new detector in India, geographically well separated from the existing LIGO-Virgo detector array, will dramatically improve the source-localization accuracies (5 to 10 times), thus enabling us to use GW observations as an excellent astronomical tool.

Impact on Indian science, industry and education

Impact on Indian science: The proposed LIGO-India project will help Indian scientific community to be a major player in the emerging research frontier of GW astronomy. A major initiative like LIGO-India will further inspire frontier research and development projects in India. The nature of the experiment is intrinsically multidisciplinary. It will bring together scientists and engineers from different fields like optics, lasers, gravitational physics, astronomy and astrophysics, cosmology, computational science, mathematics and various branches of engineering. In order to fully realize the potential of multi-messenger astronomy, the LIGO-India project will join forces with several Indian astronomy projects. Potential collaborators include the Astrosat project, future upgrades of the India-based Neutrino Observatory and optical/radio telescopes.

Impact on industry: The high-end engineering requirements of the project (such as the world's largest ultra-high vacuum facility) will provide unprecedented opportunities for Indian industries in collaboration with academic research institutions. LIGO project has facilitated major industry-academic research partnerships in USA and Europe, and has produced several important technological spin offs. LIGO-India will provide similar opportunities to Indian industry.

Courtesy : LIGO India website

Insights in physics

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Everyone of us would have experienced the immense satisfaction of understanding a concept or a phenomenon, etc. All of us cherish insightful arguments. Physics is replete with such ingenious thoughts. I wish to draw your attention to two such instances. These are not from the main stream physics of those times. Nevertheless, the ingenious ideas described here would en- thral us. In the year 1858, J. J. Waterston attempted to find the size of a water molecule. He went about modeling water to be made of water particles (molecules in modern parlance). He further assumed that each particle is surrounded by six other particles (nearest neighbours) if it is not on the surface. On an average, let there be N particles per centimetre(cm). That makes N3 particles per cubic centimetre (cc). Since there are six nearest neighbours per particle in the interior, evaporating 1 cc of water would require breaking 6N3 bonds requiring 6N3ë joules (J) of energy, where ë is the energy required to break one bond. But this energy is essentially the latent heat of vapourization (J/cc). Every water particle on the surface is supposed to have only five nearest neighbours, four in the plane of the surface and one below the surface. If this connection due to a bond per particle with the surface below is broken, a new surface is created. There are N2 particles per unit area and the energy required is N2ë J. The amount of energy required to create one unit area of surface is the surface tension (J/cm2). From these arguments, one obtains the ratio of the latent heat to the surface tension to be 6N. As there are N particles per cm, the inter-particle distance is 1/N cm. Surface tension and latent heat of vapourization are macroscopic quantities that can be measured. In the case water, these values are 72×10^{-7} J/cm2 and 2264 J/cc respectively. Using these values, the size of the water particle is estimated to be 1.9 Angstrom units. It is of interest to note that the current experimentally measured size of water molecule is 2.7 Angstrom units. That Waterston was able to estimate the size of water molecule in the year 1858 is indeed amazing. Next, let us consider the question of finding out the current carriers in metals. This issue was addressed by Stewart and Tolman in the year 1917. Their idea was to suddenly accelerate a piece ofmetal. Whichever species, electrons or positive ions, is free to move would lag behind in the direction opposed to the direction of acceleration. If electrons are mobile, the sudden acceleration would lead an accumulation of electrons in the rear end of the metal. This charge accumulation could be measured by Stewart and Tolman using ballistic galvanometer. The results were in-deed found to be consistent with mobile electrons. A masterful use of the inertia of the electrons helped in identifying the current carriers in a metal. Of course, many more examples of insightful theories and experiments could be identified. These could even be good pedagogical aids.

APT welcomes honorary members.....!

S. SIVAKUMAR

Present Position : Scientist – G
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Kalpakkam 603 102

Dr. S. Sivakumar completed PhD in Quantum Optics from IIT-Madras in 1999. He Received Laskar Award for the Best PhD Thesis in Physics from IIT-M, Chennai. He has published about 20 research articles in different international journals, most of them single-authored. He is a versatile teacher and he has been teaching different theoretical and applied subjects in the BARC training schools at Kalpakam and Hyderabad since 2001.

Referee for the following journals:

1. Journal of Physics A: Theoretical and Mathematical (IOP, London)
2. Journal of Physics B: Atomic, Molecular and Optical (IOP, London)
3. Pramana
4. Canadian Journal of Physics
5. International Journal of Theoretical Physics
6. Journal of the Optical Society of America B

Project Guidance :

1. Summer Project by Mr Y Rohin Kumar, II Year BTech, BITS, Pilani (2006)
   Topic: Dynamics of harmonically trapped two-level system
2. KVPY project by Mr. Kaushik Parasuram of BITS, III Year B.Tech, BITS, Pilani (2007)
   Topic: Quantum Lattice Solitons

Member of the Board of Studies in Physics, PSRK College for Women, Coimbatore (2012-2014)

IGCAR's Coordinator for Joint Entrance Screening Test (JEST)

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Prof. M C Valsakumar

Prof. M. C. Valsakuamr is an Alumnus of Calicut University. Soon after his M.Sc (1975- with Gold Medal) he joined the prestigious BARC training School of DAE, Govt. of India. Since then he was at IGCAR Kalpakam till he Superannuated as Outstanding Scientist and Head of Materials Physics Division , IGCAR i n 2012. Apart from various internal projects which he took up and completed successfully, Prof. Valsakuar is a versatile researcher. He has published more than 160 research article in reputed international journals including many PRLs and a dozen of PRBs. Some of his seminal work on open quantum systems and statistical mechanics become a land mark on those subjects. His research interest span from QFT to Material Science. He has also worked with great Indian Physicist ECG Sudarshan.

Many scientists and various university students graduated (PhD) under his able guidance. He is also an expert n high performance computing and was instrumental in developing dedicated computational felicities at IGCAR. Soon after he left IGCAR he was invited as a Distinguished Prof. at School of Materials E ngineering/Science, University of Hyderabad. He was at HCU for 2 years and this year he accepted the invitation to be a faculty of IIT -Palakka d .

Prof.Valsakumar is also an amazing teacher. He has taught to great effect at the APT national workshops on Langrangian Dynamics in June 2015 and Rigid Body Dynamics in December 2015.

Dr. S.V.M. Satyanarayana

- Completed MSc-Ed from Regional College of Education, Mysore
- PhD from IGCAR, Kalpakam in 'Chaos and Nonlinear Dynamics'.
- One year Post-doctoral Fellowship at Germany in 'Theoretical Modeling in Biological Cell Migration'.
- 1999 - 2006 : Worked as Scientific Officer at IGCAR, Kalpakam.
- Joined Dept. of Physics at Pondicherry Central University in 2006. Currently he is a faculty there.
- Areas of research : Computational Statistical Mechanics, Quantum Information Theory. He has published about 20 research articles in different international journals.
- From 1996 onwards he has been conducting free training programme in theoretical physics for post graduate students and those who would like to pursue research in physics. His Sunday Physics classes at the Nuclear Physics dept., Gindi campus of Madras University have gained much attention. This effort has been reported by national media like Outlook magazine and The Hindu daily.
- He has been involved in the APT workshop series in theoretical physics right from its inception in November 2014 and he has been one of the chief resource persons of these workshops. More than any other person, he is the one who has helped realize this series, and he continues to be a source of inspiration to all of us teachers.

Honorary membership to Dr S Sivakumar, IGCAR, Kalpakam

Honorary membership to Dr. M.C. Valsakumar IIT-Palakkad

Honorary membership to Dr S V M Satyanarayana Pondicherry Univeristy

APT Workshop : Magnetostatics - KMM Govt Women's, Kannur - 4-5 June 2016

APT Workshop : Electronics Experiments - 1 - Providence, Kozhikode - 14-15 November 2015

APT Workshop : Rigid Body Dynamics - CUSAT - 19-21 December 2015

APT Workshop : Special Theory of Relativity - UC, Aluva - 14-15 February 2016

APT Workshop : Central Force Problem - Christ College, Irinjalakuda - 17-18 October 2015

APT Workshop : Relativistic Electrodynamics -Christ College, Irinjalakuda - 7-8 January 2017

APT Workshop : Electronics Experiments-II -Providence College, Kozhikode - 10-12 December 2016

Neutrino Oscillations


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Department of Physics, Cochin University of Science and Technology

1. Introduction to Neutrinos

Neutrinos are the second most abundant particle in the universe after photons, in-order to fully understand the universe we live, we need to understand the properties of neutrino. The Standard Model (SM) of particle physics explains the physics of fundamental particles, there are 6 quarks and 6 leptons in SM, it also contains 4 force carrier particle, gluon (strong nuclear force), photon (electromagnetic force), and weak force carries (W ± and Z 0). Neutrinos are in the lepton family, neutrinos are the lightest leptons with no charge and 1/2-spin, out of 6 leptons there are three neutrinos. It includes electron(e^-), muon (μ^-), tau(τ^-), and three corresponding neutrinos, electron neutrino (νe), muon neutrino ($\nu\mu$), and tau neutrino ($\nu\tau$). Standard Model consists of three generations of particles and each generation has two quarks a neutrino and a charged particle (each column in figure 1). The anti-particles of these particles are also part of standard model.

The quarks interact via the strong and weak nuclear force while the leptons interact via the electromagnetic

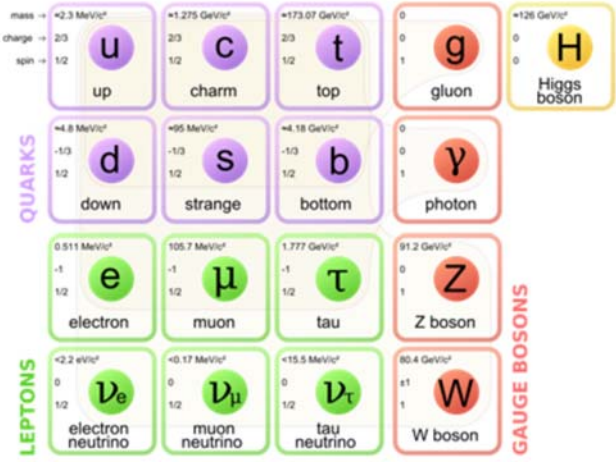

Figure 1: List of particles in Standard Model, it includes 6 quarks, 6leptons, 4 force carries and a Higgs Boson. For quarks and leptons, particle mass is in the increasing order as one go from left to right

or the weak nuclear force. SM neutrinos are massless and have no electric charge, therefore, unlike the other particles, they only interact via the weak nuclear force. Neutrino actually means "little neutral one". Since the weak nuclear force only acts at shot ranges, neutrinos can pass through massive objects without any interaction. Recently discovered particle at CERN, the Higgs boson is also the part of standard model, which gives masses to all other particle.

Neutrinos are produced during the radioactive decay of the elements, one example is β-decay, where neutron converts into proton and electron along with a neutrino.

$$n \rightarrow p + e^- + \bar{\nu}_e$$

Neutrinos are everywhere around us, it permeate the space all around us, it can be found throughout our galaxy, in the sun etc. Every second trillions of neutrinos are passing through your body. But there is no need to become alarmed for these tiny particles barely interact with anything. In fact, they can even pass through the entire Earth without being affected.

Neutrinos are massless in SM, the massless neutrinos always travels with the velocity of the light and thus the helicity (the projection of the spin along the momentum) of neutrinos is a relativistically invariant quantity. So we observe only left handed neutrinos and right handed anti-neutrinos in nature (see Figure2).

2. Origin of Neutrinos

The first two decades of the 20th century witnessed number of physicists addressing the postulate that the electron produced in the β-decay of an atom had a unique energy, not a continuous distribution, as it is a two-body decay, the energy of electron coming should have a unique energy. But the observed e^- spectrum was rather continuous. In 1930 Pauli proposed a remedy for this problem, he argued that a massless,spin-1/2, neutral particle are also coming along with electron during the process of beta decay. He named it as "neutron", and the continuous spectrum would then explain by assuming that the energy is sharing between electron and this "neutron". In 1932, James Chadwick discovered

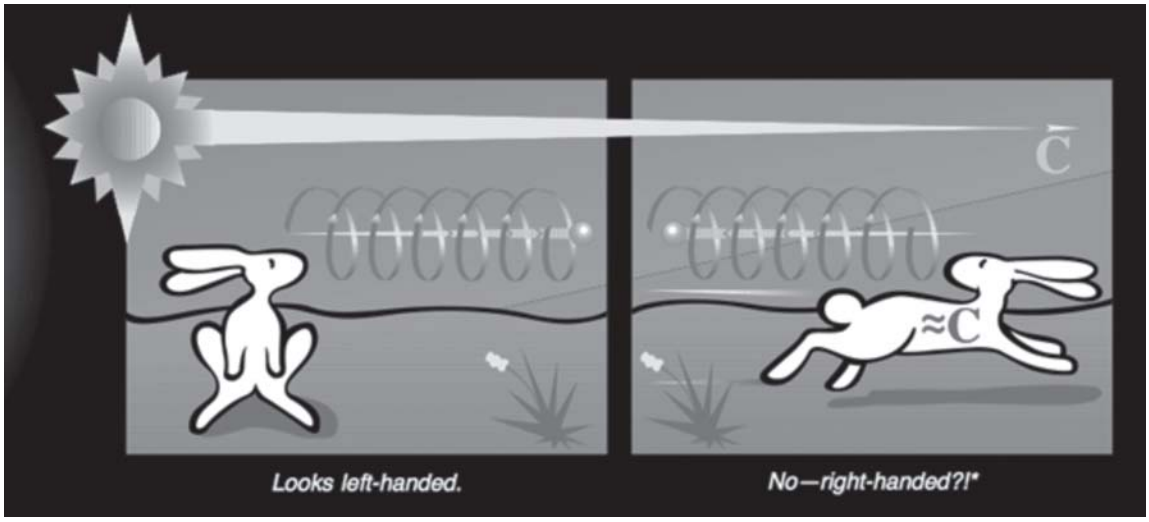

Figure 2: In SM, neutrinos are massless, as it is mass- less it can travel with velocity of light, no matter how you look at it, it always does look the same. So we say only left-handed neutrinos and right handed antineutrino exists.

the real neutron, and then Fermi renamed Pauli's particle as neutrino. Twenty year later in 1953, two American physicists Clyde Cowan and Fred Reines at the Hanford reactor site discovered the first neutrinos through the inverse β-decay process. Cowan and Reines have been awarded the Nobel prize in physics in the year of 1995 for the discovery of neutrino.

3. Neutrino Oscillations

After the discovery of neutrinos in 1955, neutrino research has became popular, and people started looking at the neutrinos coming out from the different source, like sun, atmosphere, reactor etc. There are theoretical model which tells us the flux (number of neutrinos coming out from a source). The experiment in late 60's first observed that the neutrino(νe) which is coming out from sun is half less than what we expect from the theoretical solar flux models, it turns out as a serious problem in particle physics. Later the same phenomena was observed in atmospheric neutrinos sector too, where the initial neutrino flavour is mostly muon-neutrino(νμ). Initial thought was that the theoretical models were wrong, but later it is discovered that it is because of the phenomena called "neutrino oscillations".

Neutrinos created in one flavour (νe or νμ or ντ) will undergo conversion as it propagates. This is fundamentally a quantum mechanical effect. Neutrino oscillation can be interpreted using the quantum mechanical superposition principle, the neutrino which produced with distinct flavour are superposition of mass eigenstate (ν1, ν2 or ν3) and this mass eigenstate and flavor eigenstate are connected by a 3 × 3 unitary matrix, called Pontecorvo-Maki- Nakagawa-Sakata matrix (PMNS matrix).

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu\tau \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

Here the matrix elements are basically the measure of the mixing angles, which tell us the flavour content in a particular mass eigenstate. A 3 × 3 matrix can be parameterized using 3 mixing angle and a complex phase. The strength of this complex phase determine the value of CP-violation (why particles and anti-particle behaves differently) in neutrino sector. CP-violating phase tells us why we have matter dominant universe, this is one of the interesting question that future neutrino experiment is going to answer. The discovery that neutrinos can convert from one flavour to another leads to the conclusion that the neutrinos have non-zero masses and this is a major milestone for elementary particle physics.

4. Measuring the Oscillations

Using the simple quantum mechanics calculation we can find neutrinos flavour changing probability . The probability that a muon neutrino (νμ) having energy E, appears as an electron neutrino (νe) after travelling a distance L can be written as ,

$$P(\nu_\mu \to \nu_e) = \sin^2(2\theta) \sin^2\left(1.27\Delta m^2 \frac{L}{E}\right)$$

The formula is a simple two-flavour oscillation probability, where, Δm^2 is the mass-squared splitting between two mass eigenstate, and è is called neutrino mixing angle.

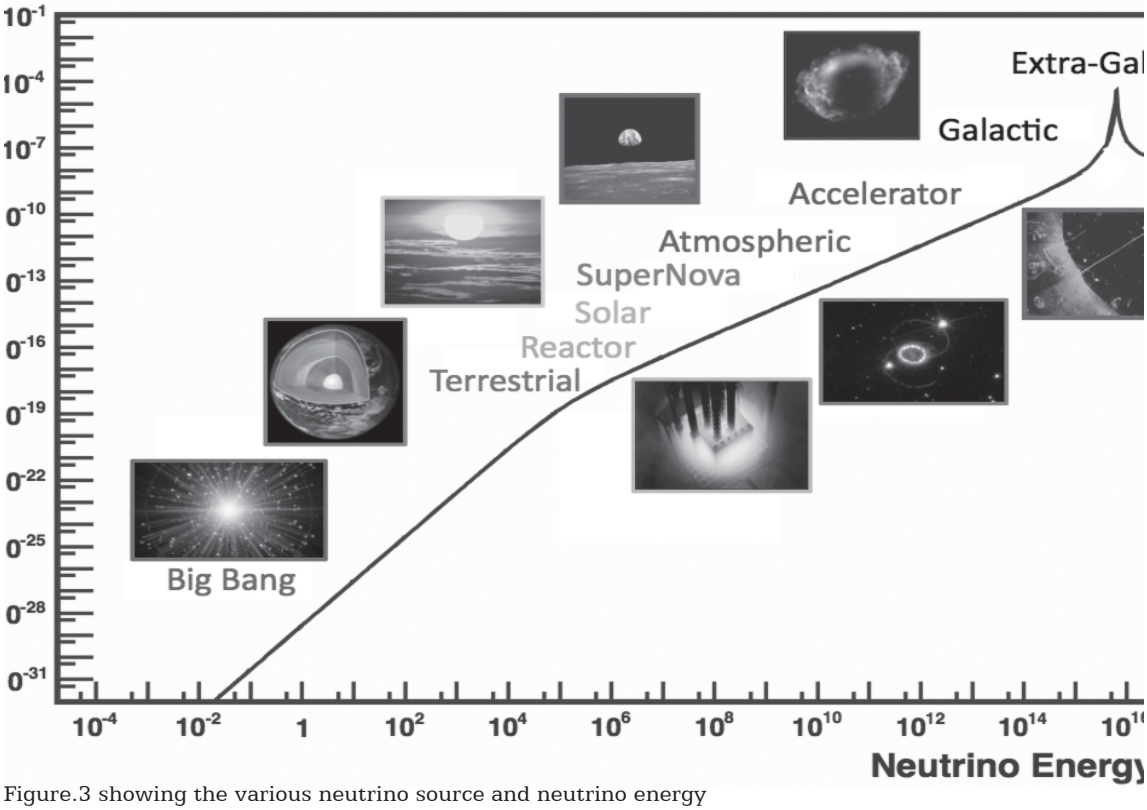

Figure.3 showing the various neutrino source and neutrino energy

Aim of every neutrino experiment around the world is to measure this mixing angle and mass-squared splitting using the probability equation. The neutrino oscillation is experimentally confirmed in 1998 at Super-Kamiokande detector at Japan in atmospheric sector (using νμ) and in 2001 in Solar neutrino sector (νe) at Sudbury Observatory Canada. Arthur B. McDonald and Takaaki Kajita was awarded the Nobel prize for physics in 2015, noble committee quoted that "for the discovery of neutrino oscillations, which shows that neutrinos have mass". The discovery of neutrino oscillation is the first evidence that the Standard Model is not complete and needs extensions. Neutrino detector use neutrinos produced at atmosphere, sun, accelerator based neutrinos and reactor neutrinos under the study. The energy and type of neutrinos depending on the source of neutrinos.

There are big detectors around the world which are exclusively built for the study of neutrino interaction and oscillation phenomena. It has been almost 75 years that neutrino is part of the particle physics, and we know only very a little about these tiny elusive particles. Still we do not understand these particles. There are still questions like what is the mass of neutrinos?, Do they violate CP?, Nature of neutrinos (Dirac or Majorana), Whether there exists more than three neutrinos etc. Future neutrino experiments will answer these questions.

Some of the important neutrino detectors around the world are MINOS (Fermilab), NoíA (Fermilab), T2K (Japan). Each experiment is sensitive to some of the mixing angles in the PMNS matrix, not to all parameters. These experiments are built to study the neutrinos produced at the accelerators and have two detectors, one near to the neutrino source and one at far away place from the neutrino source. By measuring the number of neutrinos at the near detector we can predict the number of neutrinos which are arriving at the far detector with oscillations and without oscillations and the observed data points can be compared with the prediction. It was observed that the data points are well described by the oscillation hypothesis. As a part of the project, India-based Neutrino Observatory (INO), India is also building a big iron detector at Theni (Tamil Nadu) for studying the properties of atmospheric neutrinos. Since the time of discovery itself, neutrino has been fascinating the particle physics world. Stay tuned to know more about these elusive particles.

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Space-time curvature and Gravity


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Abstract

The idea that gravity is curvature of the space-time is often said to be hard to digest. Here we explain this concept through some simple analogies, which makes easy to understand this concept in relatively easy way.

1 Introduction

The story goes like this some time in 1665, an young man named Issac Newton, while sitting under an apple tress, curious about the falling of apple to the ground, may be why it is not going up? This initiates the very rst law of gravity. The triumph of this theory is the explanation of the Kepler's law which was postulated following the analysis of Tycho Brahe's observational data. But the subtle question then remains is how light aect gravity. As such there is no answer to this question in Newtonian theory. It look a almost 300 years since then to understand the eect of gravity on light. This in through the celebrated theory General Relativity by Albert Einstein. General Theory of relativity was introduced by Einstein in 1915. It is generalization of the special theory of relativity. Special theory was formulated for inertial frames and is an extension the Galelion relativity for fast moving particles. Both Newtonian theory and special theory was exclusively for inertial frames. However both theories failed to answer why these class of frames are favored. The laws of nature must be the same for all frames of references. So in a more general sense the physics is to formulated with respect to non-inertial frames. In fact general relativity theory is such a theory and it become the modied theory gravitation.

Mechanical laws got its fundamental structure dierent from that of Aristotle when New-ton came up with his ideas. The problems with the denition of force introduced by Aristotle were replaced by Newton through his three mechanical laws. This was the starting point of classical mechanics. Newton's rst law states that a body remains in its state of rest or of uniform motion in a straight unless compelled to change that state by an external unbalanced force. It was essentially Galileo's law of inertia but restated. The phrases 'state of rest and uniform motion in a straight line' means that there may exist frames of references with respect to which the given body is absolutely at rest or moving with constant velocity. These frames are called inertial fames. This implies that there exist fundamental frames with respect to which we can identify bodies which are at absolute rest. In order to clarify the characteristics of such a frame, Newton introduced the idea of Absolute space, which is present everywhere in the universe and is immovable. A body can be at rest if it is not moving relative to this frame and the absolute velocity of a body can be observed relative to this. However Newton doesn't give any information about the properties of absolute space. Absolute space exists, in its own nature, without regard to anything external, remains always similar and immovable. Inertial frames are dened with respect to this absolute space. Any frame stationary with respect to absolute space/ fundamental frame are inertial and any frames moving with uniform velocity with respect to fundamental frame are also inertial. Anything that gets accelerated with respect to absolute space will be act up on by ctitious forces. These are forces which have no origin. This was proved by Newton through a rotating bucket experiment. In that

experiment, a bucket is hanged by a rope and is lled with water. When a twist is given to the bucket or rope, the water surface is found to be curved and eectively Newton gave explanation to the curvature as follows: Curvature is due to the action of absolute space. Whenever something is accelerated with respect to absolute space, these sort of inertial forces (centripetal, centrifugal, Coriolis force etc..) acts up on it. I.e. absolute space shows its presence by these sorts of forces on accelerating frames of references. According to Newton's third law of motion, for every action, there is an equal and opposite reaction. So by third law, the accelerated system considered above should act back up on the absolute space. But when something acts up on the absolute space, it will never be an absolute space. So Newton ruled out this reaction of matter on space. Bishop Berkeley and Ernst Mach argued against Newtonian formulation and proclaimed that the matter act back on space too, which in turn take away the absoluteness of space.

Mach gives another prescription for identifying an inertial frame. According to him, frames which are far apart can be taken as suitable inertial frames. In summary, the major shortcomings of Newtonian mechanics are as follows:

1. Concepts of absolute space need some more claricatio ns. How it can be dened in general?
2. This laws are formulated only for inertial frames. But in nature, there seems no reason to favor such a frame. Even the earth itself is not an inertial frame in its strict sense.
3. In Newtonian mechanics, inertia of a body is its inherent property. But Mach argues that the property inertial of a body is induced by the presence of other bodies around it. This was explained as below: Imagine a single body in otherwise empty universe. In the absence of any bodies, there will not be any force acting on it. Newton's second law can then be written as

$$F = ma = 0$$

Following Newton, this implies,

$$a = 0;$$

The body moves with uniform velocity. But we have no method to measure this acceleration due to the absence a proper frame reference. Hence a = 0 has no operational signicance. So the possible solution m = 0 or measure of inertia is zero, so that a single body cannot have inertia. This implies: \Inertia of a body depends on the existence of background in such a way that in the absence of the background, the measure vanishes". Thus we have the Mach's principle that \inertia is the property of matter as well as of the background. i.e., Frames which are far apart can be taken as a suitable inertial frame for us. Newtonian mechanics and special theory of relativity: When Maxwell formulated the theory of electrodynamics, it was found that the equations of electrodynamics were not t into the framework of Newtonian mechanics. The problem was that Newtonian mechanics were found to be invariant under Galilean transformations but Maxwell's equations were found to be invariant under Lorentz's transformation where time is also relative. So there is a need to change either classical mechanics so that it is invariant under Lorentz transformation or modify electrody-namics, to be invariant under Galilean transformation. Later Einstein showed that, the Lorentz transformation is the fundamental transformation and Galilean transformation is only an approximation at slow speed. By taking time as relative and velocity of light as the ultimate speed of any body or force propagation, Einstein nally formulated the mechanics for inertial frames satisfying Lorentz transformation, called special theory of relativity. Whether it is Newtonian Mechanics or Special theory of relativity, they are formulated for the special class of frames, the inertial frames. Both theories couldn't answer why these frames are to be favored over other general frames. Forces rose in these frames with denite origin, for example electrostatic force is originated from charge; gravity is originated from mass etc.

2 Newton's law of gravitation:

Universal law of gravitation due to Newton state that there exists a force of attraction between any point masses and is given as,

$$F = \frac{Gm_1m_2}{r^2}$$

Here m1;2 are called the gravitational masses and G is the fundamental constant of gravitation. This law got its universal nature due to The omnipresence of gravitational force in the universe and it's invariance under the galelion transformation. The force has no bounds means it is innite i range.

The immediate success of the Newton's law is that it explains the Kepler's laws of planetary motion, which are postulated by Kepler using Tycho Brahe's observational data. So in that sense it unies the mechanics of cosmic bodies and the terrestrial mechanics. Another triumph of the newton's law is the prediction of planet Neptune, form the irregular orbital behavior of the planet Uranus. Neptune was discovered later exactly in the same

location as predicted by the Newton's law. In spite of all these successes Newton's law of gravitation the has some limitations.

1. Fails to explain the precession of Mercury's perihelion:

According to Newton's law, Mercury's orbit an ellipse. But it was observed that the orbit is not a precise ellipse but perihelion will precess. Perihelion refers to the nearest orbital position of the planet to the sun. The shift in the perihelion was observed to be $1^0 33'20''$ per 100 years. Due to the presence of other planets, Newton's law was able to predict the precession only up to $1^0 32'37''$. The discrepancy between the theory and observation was only 43" per years. Position of the perihelion is changing. So based on Newton's laws, 43" per 100 years remained as a puzzle. Even though the discrepancy is seems to be small, it is still larger than the observational error, so can not be neglected and any faithful theory must account for that.

2. Newton's universal law of gravitation failed to explain how gravity eect the Path of light.

The light is considered to be massless corpuscles, so they are not aected by gravity.

3. It not satisfying the special theory of relativity:

According to Newton's law the gravitational interaction between bodies will propagate with innite velocity. This is against the notion of special relativity according to which nothing can propagate with speed greater than that of light.

General Theory of Relativity (GTR) which became the milestone in modern physics, which is a modied theory of gravitation too.

3 General Theory of relativity

In general theory relativity formulated by Einstein, the principle equivalence is the fundamental one.

3.1 Principle of equivalence

From the time of Galileo, it was known that the all falling bodies falling towards Earth, accelerated equally. A falling body will experience a force graviton

$$F = \frac{Gm_1m_2}{r^2} = m_g g$$

Identifying GM/r^2 as g; the acceleration due to gravity. From the point of view of Newton's mechanical law, this can be considered as action of the force F on the body of inertial mass mI hence it is getting the acceleration a; i.e.

$$F = m_I a \tag{3}$$

From equations (2) and (3, it can be written as,

$$m_I a = m_g g \text{ hence } a = \frac{m_g}{m_I} g \tag{4}$$

Since the acceleration of all freely falling bodies are the same irrespective of their nature and combination or mass, it can be concluded that the ratio m_g / m_I is the same for all bodies in the universe. In Newtonian formalism this ration is taken as one without any reason. Even though, the observation of pendulum and Eotvos experiments using torsion pendulum, proves that $m_I = m_g$; the Newtonian formalism does give any reason for this equality. In Einstein's theory is taken as basic postulate or principle, that the inertial mass and gravitational mass of a body are equivalent and is known as the weak principle of equivalence.

The consequence of the equivalence between the gravitational and inertial masses leads to the strong principle of equivalence. Considering a freely falling frame which is initially at height h from the ground. Let the direction of free fall is along thez axis, then the z' coordinate of the freely falling frame and that of the rest frame, z are related as,

$$z' = z - {}^1/_2\, gt^2 \tag{5}$$

Dierentiating the above twice with respect to time, we get the relation between acceleration as

$$a' = a - g \tag{6}$$

Consider a body of mass mI in the stationary frame in the ground which is subjected to a force of gravity mgg and non-gravitational force FNG;

$$F = m_g g + F_{NG} \tag{7}$$

From equation (6), $a = a' + g$; hence the force equation can be written as,

$$m_I(a' + g) = m_g g + F_{NG}$$

If $m_I = m_g$ the above equation implies that,

$$m_I a' = F_{NG} \tag{8}$$

which means that the in the freely falling frame there is no gravity. So it is possible to transform over to a freely falling frame where the gravity is nullied. this is known as the strong principle of equivalence.

The above description can viewed is a dierent way as follows. Let us consider a frame of reference far away from any matter so that it is completely free from the inuence of any gravitating mass. Consider that the frame is suddenly accelerating up with acceleration equal to the acceleration due to gravity. Then an isolated observer inside this accelerating starts feeling the presence of force like gravity. Let the height of such remote frame from the ground is L(t) say. The moving

frame accelerating up along the Z direction same as the direction of z′ axis of the moving frame. The relation between the coordinates is,

$$z' = Z + {}^{1}/_{2}\, gt^2 \qquad (9)$$

Then the accelerations are related as,

$$a' = a + g \qquad (10)$$

Writing the Newton's law in the accelerating frame will then become,

$$m_I a' - m_I g = m_I a \qquad (11)$$

This implies in the upward accelerating frame, there develops a force of gravity, mIg (of course $m_I = m_g$). From this one can conclude that an accelerating frame is equivalent to gravity.

3.2 Accelerating frame and Structure of space-time

We have seen that there are arise a force of gravity in an accelerating frame. This leads to the basic principle that, an accelerating frame is equivalent to gravity. More interesting is the fact that the structure of the space-time inside an accelerating frame is no longer be at. The geometry of the space-time will be altered due to the acceleration of the frame. Consider the transformation equation(5),

$$z' = z - {}^{1}/_{2}\, gt^2 \qquad (12)$$

Here we are considering two frames (z,t) which is rest and (z′, t) which is accelerating with acceleration equal to the acceleration due to gravity. In the both frames the times are the same, because of the assumption that velocity is comparatively small, so no time dilation eects are relevant. let us assume that the acceleration due to gravity $g = 10 m/s^2$:

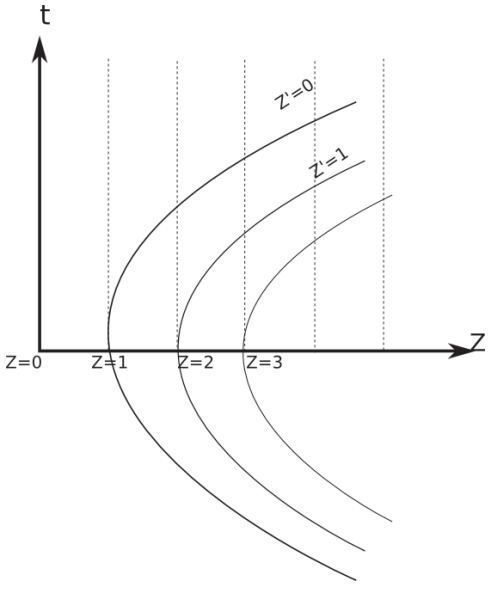
Let us probe more the transformation relation given above in a geometrical way. For getting the structure of space-time in the acceleration frame we are constructing the space-time diagram as follows. Fix the value of z′ and draw the behavior of z versus time t. The figure will be as shown in figure1 In the gure the straight dotted line parallel to the t- axis is the space-time trajectory for frame moving with constant relative velocity, where the transformation relation given by the equation

$$z' = z - vt \qquad (13)$$

The straight corresponding to this equation shows that the corresponding space-time is flat.

While parabolic lines are those corresponds to the transformation (5). Since the frame is accelerating in this case, the trajectory is become curved. The shape of the trajectory is curved because the space-time itself be curved. That in an accelerating frame the space-time is not at but curved. Invoking the principle equivalence that the an accelerating frame is equivalent to gravity, one can conclude that, in the presence of real gravity also the space- time is curved. So gravity is now manifesting as the curvature of the space. As one knows the real gravity is due to matter, so wherever there is matter the surrounding space-time will be curved.

The idea that gravity is curvature in the space-time because of the presence of matter, is so revolutionary that it take away the status of gravity as a force as stipulated by the Newtonian theory of gravity. Now may ask, then why the planets revolving the sun, is not due to the centripetal force given by the gravitational attraction between the sun and the planets? Well, it is true that the trajectory of the planets are so curved that, they appear to revolves the sun, but this curvature in the trajectory is due to the intrinsic curvature



of the space around the sun. In that sense the planets are executing a true straight motion around sun, but because of the intrinsic curvature of the space, these straight lines, otherwise known as the geodesics, are appeared to be curved, in fact they are still straight line but on curved space. This is the central concept of the Einstein theory of gravity. Thus the theory propounds that the equation representing gravity a relation between matter (equivalently energy) and the curvature caused by it.

REPORT OF THE APT KERALA ACTIVITIES 2014-2015

Dr. Shaju K.Y.
Secretary, APT

Respected President of the meeting, Prof.M.K.Jayaraj, respected office bearers, respected executive Committee members and dear APT member fraternity

With deep sense of gratitude, let me present before you the report of the academy activities for the year 2014-15. First of all, I am thanking each and every one of you for electing the new office bearers for the year 2014-16, which includes myself as the Secretary. The new office bearers of the Academy has assumed charge from 1st March.2014 onwards. As all of you know, Academy of Physics Teachers, Kerala is the only Professional body of University and College Physics Teachers in Kerala, whose sole purpose is the academic activities in Physical Science in th state of Kerala. The various activities held during 2014-15 are given below.

100 th year of Bohr Atom Model : Celebrations throughout Kerala. With the financial help from KSCSTE, Thiruvanathapuram, and in collaboration with Christ College, Irinjalakuda, APT celebrated the centenary celebrations of Bohr Atom model, throughout the state. The inauguration of the project was done at CUSAT with a two day seminar on 28 the February 2014 and 1st March 2014. Then the project continued at 17 district centres, with seminars, exhibition, Quiz programme and various other programs. The program details are as follows.

1. Kasaragod : NAS college Kanhangad : Local co-ordinator: Dr. Udayanandan K M :

2. Kannur : PRNSS college Mattannur :Local co-ordinator: Prof. Deepa K :

3. Wayanad : WMO college Muttil :Local co-ordinator: Prof. K.G. Biju :

4. Kozhikode : Govt. College Madappally :Local co-ordinator: Prof. Suneera. T.P. :

5.Palakkad : Mercy College, Palakkad, Local co-ordinator: Prof..Anu Kuruvila,

6. Malappuram : MES college Ponnani : Local co-ordinators: Prof. Shafna Shemeer

7.Thrissur : Vimala College, Thrissur Local co-ordinator: Dr.Malini,

8.Eranakulam : Maharajas Collge, Ernakulam,Local co-ordinator: Dr.Shaji N.

9.Alappuzha : S. D. College Local co-ordinator: Dr. Sreekanth J.Varma,

10.Idukki : Newmann's College, Thodupuzha Local co-ordinator: Dr.Joe Jacob,

11.Kottayam St.Thomas Collge, Pala Local co-ordinator: Dr. Ison V. Vanchipurackal,

12.Kottayam S.B.College, Changanacherry Local co-ordinator: Dr. Issac Paul

13.Pathanamthitta : St.Thomas College, Kozhenchery Local co-ordinator: Dr.Ninan Sajeeth Philip,

14.Kollam : S.N.College for Women, Local Coordinator : Dr. Nisha J. Tharayil

15.Thiruvananthapuram : M.G.Collge, Thiruvananthapuram, Local Coordinator : Dr.Ajithprasad

16. Valedictory program held at Christ Collge, Irinjalakuda, Local Coordinator : Prof.V.P.Anto

I also thank the Regional Coordinators, who worked hard for the successful completion of the project : The regional coordinators were

For Northern Kerala, Prof.G.Harikrishnan, Govt.college, Madappally

For Central Kerala, the regional coordinator is Prof.Shaju K.Y., Christ College, Irinjalakuda

For Kottayam area, the regional coordinator is Prof.Issac Paul., SB Changanacherry.

For Southern Kerala,the regional coordinator is Prof.Ajith prasad., MG college, TVM.

I thank the patron of the project respected Principal of Christ College, Rev.Fr.Dr.Jose Thekkan CMI for all the help he has done for the successful completion of the project. The detailed report and photographs will be uploaded to our website soon.

Expeyes Demonstration cum workshop

Academy of Physics Teachers, Kerala organised Expeyes Demonstration cum workshop in collaboration with IUAC, NewDelhi. The resource person was Dr.Ajithkumar B.P, Scientist H, Inter University Accelerator Centre, NewDelhi during August 2014 at Southern part of Kerala.. It was a one day program at each centre, which includes Expeyes (Experiment for young scientists, a Pheonix project for doing physics practical experiments with computers) and Python demo. The programme conducted at Christ College, Irinjalakkuda, Thrissur, MG College, Trivandrum, Fatima Matha College, Kollam, SB College, Changanassery,Kottayam, Neumanns College, Thodupuzha, Idukki, and S H College Thevara, Ernakulam. I thank Dr. Ajithkumar B.P. For his relentless effort for popularizing a modern technology in doing science experiments.

Talent Search Examination 2014-15

All Kerala Talent search examination was conducted for the year 2014-15 with a record number of participation from students . Academy expresses sincere gratitude to Prof.Anu Kuruvilla, Mercy College, Palakkad and all the regional coordinators for their brilliant effort to make the event a successful one. Prof.Anu Kuruvilla will present a brief report of the Talent search exam.

Website

Most of the activities, photos and the reports of the Academy are uploaded to our website www.aptkerala.org. Thanks to Prof.Godfrey Louis for taking keen interest in spending his valuable time for maintaining and updating the website. Godfrey sir also initiated a social physics discussion forum this year, www.social.aptkerala.org which is a very useful platform for academic discussions.

Workshop Series:

The big hit for this year was the theoretical physics workshop series, introduced by Prof.G.Harikrishnan, Govt. College, Madappally. Many thanks to Prof.G.Harikrishnan for his mind blowing effort in initiating and conducting the workshop series. By knowing the fact that lot of young teachers entered into the College service during last ten years., the attempt was to equip the young teachers so that the ultimate benefit goes to the physics students of Kerala. With real spirit and true sense of the Academy, he started the series with Prof.Satyanarayana from Pondicherry Central University, and three workshops are already completed. Prof.G.Harikrishnan will give a brief report of the past programs and future programs of the workshop series. It is lucky for APT to have such nice person, who is spending his time and money for the society. Once again I thank and wish him all success in future.

Video Library

APT now has a video library in which the Lectures of Prof.Satyanarayana, Prof.C.Vijayan, which are uploaded on youtube. Lot of hits on the videos shows that the international community also need more explanations and new methods to introduce Physics to the students.

Life Membership

Our aim is to bring all the Physics teachers of State of Kerala, under APT so that we will definitely get all types of people, who can lead the activities of the Academy. This year the life membership number increased from 52 to 136, so that we have got 84 new young members. The real credit for this hike also goes to Prof.G.Harikrishnan, since his idea of workshop series persuaded teachers to take Life membership. Once again I thank him for the effort taken to increase the number life members and hope this will be continued.

ID card, Certificate:

This year we issued Identity card for all Life Members. Also the Membership certificate will be issued. The details of life members will also be published on the website.

Finance

Dr.Issac Paul, S.B.College, Changanachery, Treasurer of the Academy will present the audited accounts-receipts and payments of the year 2014-2015 and the audited report will incorporate with this report after the General body meeting passing the accounts. I also thank Prof..Issac Paul taking huge pain of maintaining the account of APT.

Curriculum discussion:

Dr.Shaji N. of Maharajas College, has initiated a curriculum discussion during the workshop series.

During the workshop at U.C.College Aluva, Dr.Shaji N. introduced the idea and moderated the discussion. Prof.M.K.Jayaraj and Prof.Godfrey Louis supported the idea and Prof.G.Harikrishnan allotted some time for the curriculum discussions during the future workshops. Lot of youngsters are throwing their ideas and worries during the discussion. After several series of discussions, the consolidated report has to be submitted to the Higher education council for the complete restructuring of the Physics curriculum in the state.

Self criticism

Without self criticism, no organisations/establishments will progress. The APT faced two shortcomings this year.

1. We could not renew the registration of the Academy for the last seven years. I appreciate the efforts taken by Dr.Issac Paul and Dr.Santhosh Potharay and hope the renewal process will be completed soon.

2. Also we could not release APTUNES journal for the last year. I appreciate the efforts taken by Dr. N. Shaji and Dr.Santhosh Potharay and hope we can soon release our Journal. Special thanks to Prof.M.K.Jayaraj, the president of the Academy, without his support, the Acedemy could not have so much activities this year. Also thanks to Dr.Jayaprakash, formet Secretary, for his timely advice. The Academy express sincere thanks to all its members for their constant support for the year 2014-15 and expect more support for the coming years.

Thanking you ,

Prof. Shaju K Y	M.K. Jayaraj
Secretary	President

Report presented to the General body meeting held on 7.3.2015 at Dept. of Physics CUSAT, Kochi.

APT Talent Search Examination 2015

Dr. Sudheesh P.
Co-ordinator TSE

APT talent search examination conducted annually by APT is aimed to identify and encourage young talents in Physics. The APT TSE-2015 was conducted on 19th September 2015. This year's talent search examination is highlighted by the maximum number of centres and participants. There were 61 Colleges as centres and around 2487 students applied for the examination. Out of these around 2000 students appeared for the examination. As usual the preliminary examination consisted of two parts. Part A containing 75 objectives questions and Part B of 10 descriptive problems. OMR sheets of Part A were evaluated with the help of Members of the Physics Department of VTM NSS College

STATE TOPPERS IN APT TSE 2015

Sl. No.	Name of the Candidate	Name of the College
1	GOKUL V.I.	MG College Iritty
2	STEPHY JOSE	Alphonsa ,Pala
3	HARITHA JOSEPH	UC College,Aluva
4	SHIVA PRASAD V.	MG College Iritty
5	VISHNU S. NAMPOOTHIRI	St Josephs College Devagiri
6	SEBIN JOSEPH SEBASTIAN	SB,Changanacherry
7	APARNA VIJAYAN	Assumption,Changanacherry
8	ABHISHEK A.K.	MG, Thiruvananthapuram
9	GAUTHAM VARMA K.	SB,Changanacherry
10	ANUPAMA SEBASTIAN	Providence,Kozhikode
11	VIPIN C.K.	MG College Iritty
12	JINU KURIAN	Govt.College,Kodencherry

Dhanuvachapuram. Part B answer sheet of students who have scored more than 45 in part A were evaluated by the coordinator . Parts B of 110 students were evaluated. 57 students who secured the top marks in Part A and Part B were called for an interview in Kozhikode, Kannur, Ernakulum and Kottayam regions. The Kozhikode, Kannur and Ernakulum region interview held on

9th January 2015 at Dept. of Physics, Govt. Arts and Science College, Kozhikode, Dept. Of Physics, MG College, Iritty and Dept. of Physics, CUSAT respectively. The Kottayam region interview held on 16th January 2015 at Dept. of Physics, SB College, Changanacherry. The interview board included experts from all over the Kerala.Total 55 students appeared for the interview and two were absent. All students performed well in the interview and the final rank list was prepared based on the marks in the interview and written examination taken together.

The organisers of APT TSE2015 are thankful to all regional coordinators for cooperation and support they extended for the examination. The supports from the college authorities are also gratefully acknowledged.

Special word of appreciation to Dr.Devadhas of MG College Iritty for participating maximum students in the examination. He registered 400 students in this year. Heartly congratulation to Devadhas sir.

Once again thanking you all for the cooperation and requesting the support for future endeavours.

Academy of Physics Teachers (APT), Kerala Report of the activities 2015-2016

Respected President of APT, Prof.M.K.Jayaraj, respected office bearers and executive Committee members, respected honorary members and life members and my dear friends Let me present before you the report of the academy activities for the year 2015-16. As all of you know, Academy of Physics Teachers, Kerala is the only Professional body of University and College Physics Teachers in Kerala, whose only purpose is the academic activities in the area of Physical Science in the state of Kerala. The various activities of APT, held during 2015-16 are given below.

IYL Programs

In collaboration with the SPIE student chapter at CUSAT, we organized the IYL seminars at 10 colleges across Kerala. SPIE provided the financial help and we thankfully acknowledge the same. The IYL program conducted at 10 colleges and we thank Prof.Jayaraj M.K., SPIE coordinator for the effective collaboration. Such collaborations should be continued in future also. The detailed report will be published in the APT Tunes.

Talent Search Examination 2015-16

All Kerala Talent search examination was conducted for the year 2015-16 with a record number of participation from students. APT expresses sincere gratitude to the state coordinator, Dr.Sudheesh P., VTM NSS College, Dhanuvachapuram and all the regional coordinators for their sincere effort to make the event a successful one. Dr.Sudheesh P. will present a brief report of the Talent search exam.

Regional Programs

This year, APT has selected 4 regional coordinators, corresponding to 4 universities.

- For Kannur University, Dr.Devadhasan K.V., M.G.College Iritty.
- For Calicut University, Prof.G.Harikrishnan, Govt.college, Madappally
- For M.G.University, the regional coordinator is Dr.Ison V. Vachipurackal, St.Thomas College, Palai.
- For Kerala University, the regional coordinator is Prof. Vipin Das, University College, Thiruvananthapuram.

This year APT funded Rs.5000 each to all the 4 regions to conduct suitable academic programs. The details are given below.

Kannur region

An Intercollegiate Physics Quiz competition conducted at M.G.College, Iritty on 23.01.2016 at Dept. of Physics, M.G.College, Iritty. 12 Colleges Participated with 19 Teams. First prize won by Govt. Brennen College(A team), Second prize won by M.G.College, Iritty (A team) and Third won by M.G.College, Iritty (B Team). Thanks to the coordinator Dr.Devadhasan K.V.

Kozhikode region

1. A project presentation competition for M.Sc. Physics students held at Providence Women's College, Kozhikode on 22nd September 2015. 14 students from various colleges registered for the project presentation competition. The competition was managed and judged by Dr. Abdullah K K and Dr. Rajasekharan. The winners were

   First Prize - Ambily S Nair, Govt. Victoria College, Palakkad

   Second Prize - Safna Banu.K, Farook College,Calicut

   Third Prize - Anusha K and Naziya Mohammed K T, Farook College, Calicut

2. The Post Graduate and Research Department of Physics, Vimala College, Thrissur conducted an intercollegiate Project Presentation Competition for M Sc Physics students on Monday 28th September 2015. 17 students from various colleges submitted their abstracts and 11 students among them participated in the competition. Ambily S Nair of Govt. Victoria College, Palakkad, Anusha K of Providence Womens College, Calicut and Safna Banu of Farook College, Farook secured First, Second and Third positions respectively.

   Thanks to Prof. G.Harikrishnan for completing this additional responsibility.

Kottayam region

1. A seminar competition on "Light and light based technologies" was conducted at Alphonsa College Pala on 7th December 2015. 8 higher secondary schools participated in the event. S.M.V.H.S.S. Poonjar, St. Mary's H.S.S. Bharananganam and Aravinda Vidya Mandir, Pallickathodu secured the first, second and third prize, respectively in the competitions.
2. A "Multimedia presentation competition" on international year of light was conducted at St. Dominic's College, Kanjirappally on 1 January 2016. An all Kerala Physics Quiz competition was also conducted on the same day.

Thanks to Dr.Ison V. Vanchipurackal, the coordinator of these programs.

Thiruvananthapuram Region

Report not obtained

Website

Our website www.aptkerala.org is managed by Prof.Godfrey Louis and we thank him for spending his valuable time for maintaining and updating the website.

WhatsApp group

We started a whatsApp group this year and started discussing physics related and teaching related ideas. All the members will be soon added and hope we can have a vigorous academic discussions on this platform.

Workshop Series

The theoretical physics workshop series, started in last year, continued this year also. This year we also conducted the Practical Electronics workshop. Also we plan to conduct a curriculum and syllabus workshop, which is sponsored by APT in next month. Heartfull thanks to Prof.G.Harikrishnan for his constant effort in coordinating the workshop series. The effect of these workshops will be visible after few years through the brilliant performance of physics students of Kerala.

We also thank the resource persons Prof.Satyanarayana from Pondicherry Central University, Prof.Valsakumar, from IIT, Palakkad, Prof.Sivakumar, IGCAR, Kalpakkam, Prof.Suresh from Kozhikode. Prof.G.Harikrishnan will give a brief report of the past programs and future programs in the workshop series.

Video Library

APT now has a video library in which the Lectures of Prof.Satyanarayana, Prof. Valsakumar, Prof. Sivakumar and Prof. Suresh, which are also uploaded on youtube.

Life Memberships

We are gradually approaching our aim of bringing all Physics teachers of Kerala, under the single roof of APT so that we can do lot of academic activities, which ultimately benefitted by the students. Last year the life membership number increased from 52 to 136, so that we have got 84 members. This year the number increased from 136 to 229, so that we have got 93 new members. Thanks to all

those who helped to achieve this and especially to Prof.G.Harikrishnan, since the workshop series is the real reason for the rapid increase of Life memberships. I request all the members to join atleast one new member in next year. The members details are uploaded in the website.

ID card, Certificate:

Last year we issued Identity card for all Life Members. Also the Membership certificate were issued. It will be continued this year also.

Finance

Dr.Issac Paul, S.B.College, Changanachery, Treasurer of the Academy will present the audited accounts-receipts and payments of the year 2015-2016 and the audited report will incorporate with this report after the General body meeting passing the accounts. I also thank Prof.Issac Paul taking the pain of maintaining the account of APT. I also thank Prof. Issac Paul for renewing the registration of APT during past years.

APT Tunes

We released APT Tunes journal in this year. I appreciate the efforts taken by Dr. N. Shaji and Dr.Santhosh Potharay and thank all those cooperated by giving articles.

Another edition of APT Tunes are in the preparation and hope we can soon release in next month.

Future plans

We have planned the following programs in this year

State level Presentation Contest for P.G. and U.G. Students,

State level Quiz programs for U.G.Students,

Poster/Project competition for P.G. Students,

Article/Essay writing for P.G.Students,

IIT-JAM coaching for U.G.Students,

NET coaching for P.G.Students,

Interactive sessions with Plus Two teachers and could complete only few of them. So in the next year a combined effort is needed to start these programs.

Conclusion

My heartfull thanks to Prof.M.K.Jayaraj, the president of the Academy, who continuously supported me and also corrected wherever necessary so that we could have another fruitful year for the Acedemy and had lot of activities this year.

I also thank the other office bearers and executive members for their involvement in discussions, during the executive meetings. I also express sincere thanks to all its members for their constant support for the year 2015-16 and expect the same for the coming years.

Thanking you,

Aluva	Dr.Shaju K.Y.	Prof. M.K. Jayaraj
13-02-2016.	Secretary	President

TSE 2016 - Toppers

1. Gokul .V
M.G. College, Iritty

2. Aashique Unnikrishnan
Devamatha, Kuravilangad

3. Bipin Babu
DB College Sasthamcota

4. Athira Gopal
MG College Iritty

APT Talent Search Examination 2016

Dr.Reshmi R
General coordinator, APT TSE 2016.

APT talent search examination conducted annually by APT is aimed to identify and encourage young talents in Physics. The APT TSE-2016 was conducted on 24th September 2016. There were 72 Colleges and around 2400 students applied for the examination. Out of these around 2000 students appeared for the examination.

The preliminary examination consisted of two parts. Part A containing 75 objectives questions and Part B of 10 descriptive problems. OMR sheets of Part A were evaluated with the help of Members of the Physics Department of UC College Aluva. Part B answer sheet of students who have scored more than 43 in part A were evaluated by the coordinator. Part B of 200 students were evaluated. 60 students who secured the top marks in Part A and Part B were called for an interview in Kozhikode, Kannur, Thrissur, Kottayam and Thiruvananthapuram regions in the following dates.

Kannur

Date : 21/1/2017
Venue : Nirmalagiri College, Koothuparamb

Kozhikode

Date : 21/1/2017
Venue : Govt Arts and Science College, Meenchanda Kozhikode

Thrissur

Date : 28/1/2017
Venue : St Thomas College, Thrissur

Kottayam

Date : 14/1/2017
Venue : Baselius College, Kottayam

Thiruvananthapuram

Date : 21/1/2017
Venue : University College, Thiruvananthapuram

The interview board included experts from all over the Kerala. Total 60 students appeared for the interview and four were absent. The final rank list was prepared based on the marks in the interview and written examination taken together.

The organisers of APT TSE 2016 are thankful to all regional coordinators for cooperation and support they extended for the examination and interview. The support from the college authorities is also gratefully acknowledged.

Once again thanking you all for the cooperation and requesting the support for future endeavours.

Sl. No.	Name of the Candidate	Name of the College
1	Gokul N P	MG College Iritty
2	Aashique Unnikrishnan	Devmatha College Kuravilangad
3	Bipin Babu	DB College Sasthamcota
4	Athira Gopal	MG College Iritty
5	Suryan sivadas	Baselius College Kottayam
6	Abhijith K R	MG College, Iritty
7	Aamir Sahil	C H Brennen College
8	Nikhil Joseph	MG College Iritty
9	Abhishek A K	MG college TVPM
10	Sandra Maria Jose	Brennen College

APT National Workshop Series : A Review

Dr. G. Harikrishnan
Coordinator of APT National Workshop Series
April 2017

APT National Workshop Series for the teachers was launched in November 2014. Until February 2017, in a span of 28 months, 21 workshops were completed. Out of these 16 were in Theoretical Physics series, 3 in Experimental Physics series and 2 in Astronomical Data Analysis series. Except for the two workshops in Astronomical Data Analysis series, organized in collaboration with IUCAA, Pune, all the other workshops were organized without any financial aid from Govt. or private agencies. Each of these workshops were on cost-sharing basis, using the registration fee of the participating teachers. The workshops are being conducted at different colleges in Kerala, but the participation is not limited to teachers from the state. These workshops are regularly being conducted on holidays to avoid the loss of teaching hours of the participants. APT National Workshop Series is unique in the country as this could be the only series of its kind being regularly conducted outside the demands of the service regulations, and the directives and funding of Govt. or private agencies. The model is being sustained by the continuing support of the participating teachers, the dedicated efforts of the local organizers of the hosting colleges, and the commitment of the resource persons.

2014-2015

The series began in November 2014 with bimonthly workshops in Theoretical Physics. In the academic year 2014-2015 five workshops were conducted in Mathematical Physics series.

APT National Workshops in 2014-2015

[Theory : Mathematical Physics Series]

No.	TOPIC	VENUE	DATES	RESOURCE PERSON
1	Complex Analysis	Christ college, Irinjalakuda	1-2 November 2014	Dr. S.V.M. Satyanarayana, Pondicherry University
2	Linear Algebra	St. Thomas college, Pala	26-28 December 2014	Dr. S.V.M. Satyanarayana, Pondicherry University
3	Tensor Analysis	U.C. college, Aluva	14-15 February 2015	Dr. S.V.M. Satyanarayana, Pondicherry University
4	Differential Equations	Farook college, Kozhikode	10-12 April 2015	Dr. S. Sivakumar, IGCAR, Kalpakam
5	Group Theory	Providence Women's college, Kozhikode	15-17 May 2015	Dr. S.V.M. Satyanarayana, Pondicherry University

APT National Workshops in 2015-2016

[Theory : Classical Mechanics Series]

No.	TOPIC	VENUE	DATES	RESOURCE PERSON
1	Lagrangian Dynamics	Vimala college, Thrissur	27-28 June 2015	Prof. M.C. Valsakumar, IIT-Palakkad Dr. S.V.M. Satyanarayana, Pondicherry University
2	Hamiltonian Dynamics	SB college, Changancherry	22-24 August 2015	Dr. S. Sivakumar, IGCAR, Kalpakam
3	Central Force Problem	Christ college, Irinjalakuda	10-11 October 2015	Dr. S.V.M. Satyanarayana, Pondicherry University
4	Electronics Experiments - I	Providence Women's College, Kozhikode	14-15 November 2015	Prof. V.C. Suresh, PSMO College Thirurangadi (Rtd)
5	Rigid Body Dynamics and Small Oscillations	Cochin University of Science and Technology	19-21 December 2015	Prof. M.C. Valsakumar, IIT-Palakkad
6	Special Theory of Relativity	U.C. college, Aluva	14-15 February 2016	Prof. H.S. Mani, CMI, Chennai

- 6 Workshops in 2 ongoing series
- Theoretical Physics series : **series 2 : Classical Mechanics.**

  There were 5 bimonthly workshops in this series, from June 2015 to February 2016.
- Experimental Physics series : **Electronics Experiments - I**

The thrust areas of the workshop were (i) the theory and implementation of amplifier designing and (ii) the theory and applications of OPAMP. 22 Electronics experiments at the MSc level were analyzed and demonstrated during the workshop. Predesigned circuits were made available at the venue. The participants got the opportunity to learn the designing of these circuits and make proper measurements.

2016-2017

In 2016-17 six bimonthly workshops in Electrodynamics series and two workshops in Experimental Physics series were conducted. In addition, Astronomical Data Analysis series was launched with two workshops conducted in collaboration with IUCAA, Pune.

- 10 Workshops in 3 ongoing series
- Theoretical Physics series : **series 3 : Electrodynamics.**

  There were 6 bimonthly workshops in this series, from April 2016 to February 2017.
- Experimental Physics series : **(1) General Physics Experiments -I**

  (2) Electronics Experiments - II

APT National Workshops in 2016-2017

[Theory : Electrodynamics Series]

Sl No.	TOPIC	VENUE	DATES	RESOURCE PERSON
1	Electrostatics	Providence Women's College, Kozhikode	29-30 April & 1May 2016	Dr. S.V.M. Satyanarayana, Pondicherry University
2	Magnetostatics	KMM Govt. Women's College, Kannur	4-5 June 2016	Dr. S. Sivakumar, IGCAR, Kalpakam
3	General Physics Experiments-I	St. Thomas College, Pala	29-30 June & 1-2July 2016	Dr. Ison V. Vanchipurackal, St. Thomas College, Pala
4	Astronomical Data Analysis-I : Virtual Observatory	SH College, Chalakudi	16-17 July 2016	Prof. Ajit Kembhavi, IUCAA, Pune Dr. Ninan Sajeeth Philiph, St. Thomas College, Kozhencherry
5	Electric and Magnetic Fields in Matter	Vimala College, Thrissur	13-15 August 2016	Dr. S.V.M. Satyanarayana, Pondicherry University
6	Electromagnetic Waves	CMS College, Kottayam	8-9 October 2016	Dr. S.V.M. Satyanarayana, Pondicherry University
7	Astronomical Data Analysis-II : X-Ray Astronomy	Providence Women's College, Kozhikode	19-20 November 2016	Prof. Ranjeev Misra, IUCAA, Pune
8	Electronics Experiments - II	Providence Women's College, Kozhikode	10-12 December 2016	Prof. V.C. Suresh, PSMO College Thirurangadi (Rtd)
9	Relativistic Electrodynamics	Christ College, Irinjalakuda	7-8 January 2017	Dr. S.V.M. Satyanarayana, Pondicherry University
10	Radiation	St. Xavier's College, Aluva	11-12 February 2017	Dr. S.V.M. Satyanarayana, Pondicherry University

There were 12 experiments included in the General Physics experiments workshop. The theory was discussed in detail and hands-on sessions were conducted for all experiments.

The workshop on Electronic experiments was a repetition of the first such workshop conducted in Nov. 2015, but the theoretical aspects were discussed in more detail and there was sufficient time for hands-on training.

- Astronomical Data Analysis series : **Workshop 1 : Virtual Observatory**

  Workshop 2 : X-Ray Astronomy

The aim is to train the teachers in planning and executing MSc level projects in this field. Some of these projects may be extended to PhD level work for the students as well as the teachers.

2017-2018

In 2017-18 six bimonthly workshops in Quantum Mechanics series, one workshop in Experimental Physics series, and two workshops in Astronomical Data Analysis series are scheduled.

APT National Workshops in 2017-2018

Sl No.	TOPIC	VENUE	DATES	RESOURCE PERSON
1	Genesis of Quantum Theory	Mar Ivanios College, Thiruvananthapuram	29-30 April 2017	Dr. S.V.M. Satyanarayana, Pondicherry University
2	Wave Mechanics	Assumption College, Changanasserry	10-11 June 2017	Dr. S.V.M. Satyanarayana, Pondicherry University
3	UV-Band Astronomy	(will be announced later)	15-16 July 2017	(will be announcedlater)
4	Conceptual and Mathematical Structure of Quantum Mechanics	Vimala College, Thrissur	12-14 August 2017	Dr. S.V.M. Satyanarayana, Pondicherry University
5	General Physics Experiments- II	St. Thomas College, Pala	13-15 September 2017	Dr. Ison V. Vanchipurackal, St. Thomas College, Pala
6	Angular Momentum : Hydrogen Atom Problem	KMM Govt. Women's College, Kannur	14-15 October 2017	Dr. S.V.M. Satyanarayana, Pondicherry University
7	Solar Astronomy	(will be announced later)	18-19 November 2017	(will be announced later)
8	Spin - Addition of Angular Momenta - Identical Particles - Construction of Periodic Table from Quantum Mechanics	Providence Women's College, Kozhikode	9-11 December 2017	(will be announced later)
9	Time-Independent Perturbation Theory - Variational Method - WKB Approximation	CMS College, Kottayam	10-12 February 2018	(will be announced later)

- 9 Workshops in 3 ongoing series
- Theoretical Physics series : **Series 4 : Quantum Mechanics**

  There will be 11 workshops in this series, from April 2017 to December 2018, spanning 26 days, with more than 78 hours of classes and 52 hours of tutorials. Six of these workshops will be conducted in 2017-18.
- Experimental Physics series : **General Physics Experiments - II**

  There will be 12 experiments in this 3-day workshop. This is the second part of the workshop conducted in June 2015. The theory of these experiments will be discussed and the hands-on sessions will be conducted. Intake will be limited to 36 participants.
- Astronomical Data Analysis series : **Workshop 3 : Ultraviolet Band Astronomy**

  Workshop 4 : Solar Astronomy.

  The theory will be briefly discussed and training in the software will be imparted through hands-on sessions. Intake will be limited to 40 participants.

M. G. K. Menon
(1928–2016)

Ramanath Cowsik

During the morning hours on Tuesday, 22 November 2016 Mambillikalathil Govind Kumar Menon passed away at his residence in New Delhi with his wife, Mrs Indumati Menon (née Patel) attending by his bedside. My heart goes out to Indubehn who had been his partner and companion for over 65 years – mere words cannot express our deep feelings of this loss or assuage the pain of separation Indubehn and their two children, Preeti and Anant Kumar are feeling at this time. Children who called him Goku-dada, friends and fellow scientists, administrators, entrepreneurs, industrialists, ecologists, and indeed innumerable men and women are saddened by this loss. It is only the alchemy of time, during which his great contributions to science and to the nation are recalled repeatedly, that will transform our feelings into a celebration of the remarkable life of achievement and service of Menon. A noble soul has given up the corporeal frame emaciated by decades of toil in the service of humanity – his spirit lives on.

In his own time he was a legend; there was no responsibility he could not bear and there was no impasse that he could not resolve, that he was affectionately called by his friends and colleagues as Magic-Menon, – he could make anything happen, if it was for the general good. He was born at Mangalore (Karnataka) on 28 August 1928, had his early education in Tamil Nadu, and obtained his Bachelor of Science degree studying at Jaswant College, Jodhpur (Rajasthan), affiliated to Agra University. Thence, he moved to the Royal Institute of Science, Bombay and earned his Master of Science working under the tutelage of the famous spectrascopist Tawade, at whose instance he went on to work with Cecil F. Powell (N.L.) at the University of Bristol, England. There he discovered several events in nuclear emulsions exposed to cosmic rays, showing that the same particle decayed into either two or three pions. This discovery caught the attention of Homi J. Bhabha, then the director of the Tata Institute of Fundamental Research (TIFR), Bombay. Bhabha, in his lecture and in the ensuing discussions, emphasized the importance of the discovery in the context of the need for the violation of fundamental symmetries of 'charge conjugation' and 'parity' at the International Conference of Theoretical Physics, Kyoto and Tokyo (1953) – a discovery that stimulated the theoretical work of Nobel laureates T. D. Lee and C. N. Yang. After holding prestigious postdoctoral fellowships in the United Kingdom for three years, Menon joined TIFR, Bombay, at the invitation of Bhabha and integrated himself effectively with the research groups working in the field of cosmic rays. His expertise, energy and enthusiasm added considerably to the productivity of these groups, who were already very active with programmes initiated by Homi Bhabha. With G. S. Gokhale he rapidly enhanced the capabilities in scientific ballooning; this suborbital programme was the precursor for the initiation of the highly successful space programme in India. Along with B. V. Sreekantan and his group he was responsible for the discovery of first interaction of a cosmic-ray neutrino in the deep underground detector at the Kolar Gold Fields, and for setting strong bounds on the lifetime for the decay of protons, violating baryon-number conversation. It is not surprising that he was honoured with the S. S. Bhatnagar Prize and with the election as a Fellow of the Royal Society (London) early in his career. The close rapport that was established initially between Bhabha and Menon because of their shared interests in *K*-meson physics became progressively deeper as Bhabha observed how Menon could easily integrate himself into several different groups and play the leadership role not by any authority vested in him but by his focus on the objectives and his desire to serve. As Bhabha's responsibilities grew with developing the atomic energy programme in India and in channelling international attention towards peaceful uses of atomic energy, progressively greater

responsibilities pertaining to TIFR fell on Menon's shoulders, and he soon became the main force to implement Bhabha's vision for the growth of fundamental research and a variety of technologies, not only within the portals of TIFR but also in the wider arena of independent India. Upon the untimely demise of Bhabha in an air crash over Mont Blanc in 1966, the responsibility increased multifold on Menon's shoulders, first as the Director of TIFR, then progressively as the protégé of Bhabha working for development of the infrastructure for science and technology across the country.

Tata Institute of Fundamental Research was one of the most prestigious institutions in the world and its director Homi Bhabha one of the most respected theoretical physicist and a visionary in the forefront of India's scientific and technological development. As Menon took over the office of directorship of TIFR, and was faced with the challenge of continuing seamlessly with the wideranging initiatives Bhabha had taken, he was as yet unknown to the wider community of scientists, technocrats and high-level administrators in the Government of India. Thus he was viewed with some reserve, with the question whether he can fill-in for such a great man as Homi Bhabha. With the advice and strong backing of J. R. D. Tata, support of his scientific colleagues and by the sheer strength of hard work and perseverance, Menon carried on with Bhabha's initiatives smoothly. His reputation grew steadily not only within the scientific community but also more

broadly, including in the higher echelons of the Government of India. He soon became an esteemed colleague who could be called upon to shoulder multiple responsibilities. His limitless energy, attention to detail aided by an excellent memory and a fine sensibility allowed him to function well.

In 1971 he was appointed as the Secretary, of the newly constituted Department of Electronics, Government of India, a position he held concurrently with the Directorship of Tata Institute of Fundamental Research. He set up the infrastructure for policy-making, research and development and administrative control of this department. The department under Menon funded electronics research in strategic areas, founded the National Centre for Software Development, National Informatics Centre, Computer Maintenance Corporation and several State Electronic Development Corporations to promote manufacture of electronics components, instruments and consumer products. The fruits of these efforts are abundantly visible in India today. A lesser man would have faltered under this burden of responsibilities, but the sudden demise of another Indian

stalwart, Vikram Sarabhai added further responsibilities – Menon became the interim Chairman of the Indian Space Research Organization and the Director of the Physical Research Laboratory in January 1972. As soon as Menon took charge he started a quiet search for persons of the right qualifications and temperament. Within a year's time we saw Satish Dhawan at the helm as Chairman, ISRO, and U. R. Rao as Director, PRL. It is appropriate here to note that Menon was also responsible in persuading V. Radhakrishnan, the world famous radio astronomer to take up the Director's position at the Raman Research Institute vacated by C. V. Raman's death. We know that each of these institutions have blossomed wonderfully under the new leadership, bearing ample witness not only to Menon's deep perception of the strengths of his fellowmen but also to his gentle persuasive powers which make people willingly dedicate themselves to public service.

Menon's contributions to our nation, which began so spectacularly, moved from crescendo to crescendo; he was appointed in 1974 as the Scientific Advisor to the Defense Minister with a charge to serve also as the Director, Defence Research & Development Organization. These responsibilities he would take upon in all earnestness, develop an appropriate policy and profile for their growth, find the right persons to carry out the objectives and quietly withdraw leaving them in the forefront, while his advice and support was always available just for the asking. In 1978 he was appointed as the Secretary, Department of Science and Technology, Director General Council of Scientific & Industrial Research, and subsequently as a member of the Planning Commission (1982–89), which accorded him an opportunity to draft the Technology Policy Statement (1983) and play a wider role in the national development. He was the Chairman, Scientific Advisory Committee to the Cabinet (1982–85) and Scientific Advisor to the Prime Minister (1986– 89). He served as the Union Minister for Science & Technology and for Education for a year before he was elected to the Rajya Sabha in 1990 for a six-year term.

His contributions were not limited only towards the growth of science and technology in India but also extended internationally. He initiated along with Abdus Salam (N.L.) the formation of the Third World Academy of Sciences that has been responsible over the last three decades in the growth of scientific temper and technological growth in developing countries. It is not possible to capture the measure of this great man within the compass of this brief memoriam.

Courtesy : Current Science

APT Workshop : General Physics Experiments -1 - St Thomas College, Pala - 29-30 June & 1-2 July 2016

APT Workshop : Electric and Magnetic Fields in Matter - Vimala College, Thrissur - 13-15 August 2016

APT Workshop : Magnetostatics - KMM Govt Women's College, Kannur - 4-5 June 2016

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