For Private Circulation only

BASE line

A Quarterly Bulletin of the Jawaharlal Nehru Planetarium, Bangalore Association of Science Education

Number # 3 May, 2015

Contents

25 years ago

This tree in full bloom, commonly known as Bottle Brush (botanical name: *Callistemon lanceolatus*), was planted on the day of inauguration, 19th November, 1989.

My memories of Bangalore Planetarium

- Teresa Bhattacharya

Recently, I visited the Jawaharlal Nehru Planetarium in Bangalore after a gap of many years. I had been there just once earlier for a meeting in the early nineties when I was Secretary Science & Technology in the Government of Karnataka, and it had not been possible then to go around the premises and 'see the sights'!

This recent visit took me there on what was, nostalgically, something of a journey back in time– back to 1981 when the dream of setting up the Bangalore planetarium was first born. I was a relatively young IAS officer at the time, working as Commissioner of the Bangalore City Corporation. Bangalore was a different world then - a true garden city with several large, self-contained public sector companies on the outskirts, a sprinkling of private industries, a contented population with a leisurely lifestyle, and an abundance of lovely flowering trees spreading their sheltering branches over the serene parks, roads and bungalows of the City.

It was in this setting that the City Corporation first had the idea of setting up a Planetarium as one of its major projects for the year. Bangalore was a manageable city then, and the Corporation was able to take up some special projects every year apart from their routine duties.

(Photo from her collections of Foundation Stone Ceremony for the Planetarium; show His Excellency President N Sanjeeva Reddy with Governor His Excellency Govind Narayan, Chief Minister Gundu Rao and Minister Dharam Singh along with her)

There were some favourable circumstances that helped at these early stages. Firstly, there was an excellent team in the Government and the Corporation, at both decision making and implementation levels. The then Chief Minister Sri Gundu Rao was young, enthusiastic, and supportive of good work. Sri Dharam Singh, Minister for Urban Development was a down to earth, practical Minister, a pleasure to work with. And the official team headed by the Administrator Sri Balagopalan and including excellent officers like our Chief Engineer Sri Nagendra worked together as one.

Secondly, Bangalore was (and is) fortunate to have a number of reputed scientific and technical Institutions, and this enabled the Corporation to include some distinguished experts from the Institute of Astro Physics, IISC, etc. on the Committee set up to plan for the Planetarium.

An engineer of the famous Carl Zeiss Optical Instruments firm from Jena in the then East Germany also visited Bangalore, had discussions with the Committee members and visited the proposed site of the proposed planetarium – on the banks of the Sankey lake.

After looking at several possible locations, Sankey Lake side was chosen as the ideal spot where school children and other visitors could visualize the wonders of Space, stars and planets in serene surroundings, and relax on the spacious banks of the lake. How well I remember accompanying a team, along with the visiting engineer from Jena, to visit the lake and fix the actual spot for the building.

It was a moment of crowning satisfaction for all of us involved in this project when, on the 31st of January 1982, in a beautiful setting on the banks of the Sankey Lake, His Excellence the President of India laid the foundation stone of the Corporation Planetarium, in the presence of His Excellency the Governor of Karnataka Sri Govind Narain, the Chief Minister Sri Gundu Rao, the Urban Development Minister Sri Dharam Singh and the Administrator and officers of the Corporation.

I was transferred from the Corporation a couple of months later, and was in Delhi thereafter for five years. On my return to Bangalore, I learnt that the venue had been changed, possibly because of objections from some residents near the Lake. The planetarium was later established at the present spot - the old ADE premises - centrally located and very spacious. Is it a change for the better? I really don't know!

But the warmest memory I carry of those days is the excellent co-operation and rapport among the different agencies involved: the Corporation officials, the elected representatives, the scientists and technical experts. It is only through this kind of mutual respect for different viewpoints, willing sharing of expertise, and genuine bonhomie that projects and activities like these can be truly successful.

I am extremely thankful to Dr. B.S. Shylaja, Director of the Planetarium, for bringing me back in touch with this wonderful place, and congratulate her and her team for the great work carried out here. It was a most enjoyable experience going around the planetarium, and witnessing the awesome panorama of celestial movement in the starry night sky re-created high above us in the darkened hall.

Teresa Bhattacharya, as the Commissioner of the Bangalore City Corporation in the 80's, saw the seeds of the idea of a planetarium being sown in Bangalore. She was instrumental in finalsing the location and procurement of the instrument from (East) Germany.

REAPers Speak

My research interests

- K.G. Padmalekha

I started attending REAP classes when I was in 1st PUC.The classes I attended included astrophysics by Dr. Shylaja and electrodynamics by Prof. Bala Iyer and classical mechanics by Prof. Lokanathan. I also fondly recall the series of lectures given by Prof. C.V. Vishweshwara on black hole hunt. Along with teaching the subject, they also taught me how to ask the correct questions. REAP classes have been instrumental in shaping my career and thought process and they also gave me lifelong friendships with like-minded researchers.

A plethora of new materials are being synthesized every day and it is of paramount importance that one understands the reasons behind why they are what they are. Many experimental techniques are needed to characterize and understand them thoroughly. My research interest is to use certain spectroscopic techniques to understand the structure and electronic properties of different materials. The interesting systems include magnetic nanoparticles, catalysts as well as microstructures of spin crossover compounds. I have used two different spectroscopic techniques to characterize materials. Both give valuable physical insight into the system.

During the first few years, my research dealt with electron paramagnetic resonance (ESR) technique. To put it simply, an unpaired electron is a charged particle with its own magnetic moment and when it is placed in a magnetic field, it responds differently depending on the environment it is in and gets excited. When microwaves of a certain wavelength which have the same energy as the excitation are applied to the system, one gets a resonant absorption. This absorption gives information regarding the environment the electron is in. Depending on the shape, position, width and number of peaks in the absorption spectrum, one can derive a wealth of information regarding the electronic structure of the material under investigation. ESR is a very sensitive technique that it can detect the presence of certain species in the range of parts per billion. Hence it has many applications in the fields of biology and chemistry as well. I used this technique to study conductivity in manganite nanoparticles and one dimensional organic conductors which show spin liquid behavior.

Another technique I am currently working with is called Mössbauer spectroscopy. This technique uses iron nuclei in the system under study to absorb gamma rays from a radio-active source. The position, width and shape of the absorption line give information about the oxidation state of the nucleus in the system and the nature of the surrounding electron cloud. The applications include biology, geology, chemistry and even extraterrestrial spectroscopy of soil in the Mars explorer mission. I study spin crossover compounds and Iron based catalysts using this technique.

Both these techniques give best results when the temperatures are less and sometimes high magnetic fields are required which involve superconducting magnets and they also need low temperatures to perform. Hence the involvement of cryogenic tools and techniques to obtain low temperatures also becomes part of the experimental details. I am also developing an experimental set-up for doing time resolved Mössbauer spectroscopy.

Padmalekha did PhD in the Department of Physics, Indian Institute of Science, Bengaluru; continued Post-doctoral research at Tata Institute of Fundamental Research, Mumbai, India and then in University of Stuttgart, Germany. Currently she is working as a guest lecturer at the Department of Physics, Technical University of Kaiserslautern, Germany. padmalekha@physik.uni-kl.de

Conjunction of Uranus and Venus on 5th March - photo by Pramod Galgali

The Neutrino Story

– S Lokanathan

1. INTRODUCTION:

There is a beguiling similarity between the Neutrino and the Ether of the 19th century. Each was invoked to sustain an entrenched wisdom, the Ether for 'carrying' electromagnetic waves and the Neutrino to save conservation laws of energy and momentum. The Ether has disappeared from the text books thanks to Einstein's theory of Relativity. But, the Neutrino has multiplied to three 'generations' and is now a key probe in huge experiments. The truth is that the similarity is superficial since from the start the Ether hypothesis was beset with contradictions: e.g. it was to offer no resistance to motion and yet it had to be rigid enough to sustain transverse electromagnetic waves. The story of the Neutrino was quite different. But, I am getting ahead of my story.

2. BETA DECAY CRISIS:

It begins with Ernest Rutherford naming the three types of radiations emitted by radioactive substances, a, b and g. They were identified as Helium nucleus (a), an electron or a positron ($e^{\pm}$) and a high energy photon (g). The and the were emitted in their relative processes with a definite energy as one would expect from the de excitation of an excited nucleus from a two body process:

$$(Nucleus)^{*} \longrightarrow (Nucleus) + a \quad - (1)$$

$$(Nucleus)^{*} \longrightarrow (Nucleus) + g \quad - (2)$$

But curiously, the beta particle (electron or positron) did not carry a fixed energy. Instead, in a set of identical reactions, it had a distribution of energies with a maximum. The question was what happened to the missing energy? Wolfgang Pauli had an answer; the missing energy was carried off by a particle with such properties that eluded detection, an uncharged particle of negligible mass, very weakly interacting with the other particles and carrying a half integral spin. By today's standards, Pauli's hypothesis may seem hardly revolutionary but in very few elementary particles were known – perhaps the discovery of the Newton (1932) envisaged Enrico Fermi to take Pauli's connective seriously. Indeed he baptised Paul's particle NEUTRINO and proceeded to construct a theory for the beta process.

3. FERMI'S THEORY OF BETA DECAY:

Fermi started with two important ideas. First, since the electron and the neutrino could not be normal constituents of the nucleus, they were created at the instant of the beta decay. There WAS precedent for this for, after all, though a photon emerged from an excited atom or a nucleus, one does not think of it as a normal constituent of the system. Still Fermi's was a bold step since this was the first time a theory was specifically constructed on the assumption that a particle was a quantum of a field and was created 'out of the Vacuum' as it were, from available energy and momentum. The second feature followed from the first, Fermi's theory would imitate the theory of photon emission. In other words, the weak (beta) interaction was constructed in analogy to the electromagnetic one.

Fermi's theory was landmark in the Neutrino story. Its prediction of the beta energy spectrum was in fine agreement with experiment. In particular one could deduce the mass of the neutrino from the shape of the beta spectrum near the maximum energy. At this stage experiments could only set an upper limit to the mass and were consistent with zero mass. Fermi's theory also gave selection rules, relating to the quantum states of the initial and final states of the nucleus undergoing beta decay. Research in beta decay would lead to a spectroscopy, a useful tool for studying nuclear properties.

4. NEUTRINOS FROM DECAYS OF NEW PARTICLES:

The Neutrino now was a 'respectable' particle not just in beta decays, but also as a suitable candidate in decays of a number of particles, discovered in droves in late 1940s and early 1950s. An excellent example was the decay of the pion.

$$P^{\pm} \longrightarrow m^{\pm} + (n) \quad - (3)$$

and

$$m^{\pm} \longrightarrow e^{\pm} + (n) + (n) \quad - (4)$$

Still, a 'direct' experimental proof for neutrinos was a decade ahead. What then inspired the increasing confidence in is reality? One reason was that quite specific theoretical formulations of weak interactions using neutrinos had emerged that made comparison with experiments feasible. Perhaps, the best example was L. Michel's analysis of the decay of the muon (reaction #4). Although only the electron (or positron) was detectable, Michel's analysis narrowed down the range of possible Fermi type interactions from a comparison with the observed energy spectrum.

In 1956, that F Reines and C L Cowan performed a delicate experiment that could be accepted as a direct detection of the neutrino. They used a powerful nuclear reactor as a source for (anti) neutrinos to detect the reaction:

$$\bar{n} + p \longrightarrow n + e^{+} \quad - (5)$$

The product neutron was captured by a nucleus and produced a and a positron (e^{+}) and also a pair of photons produced by annihilation of the positron. The simultaneous appearance of the and the photons was the signal for the reaction.

5. PARITY VIOLATION:

1956 was also the year when the role of symmetry in physics was forcefully brought to the forefront. It began with a puzzle involving the decay of one of the new particles (called a K meson today) in two modes which contradicted a space symmetry property of the K Meson. This led T.D. Lee and C.N. Yang to question if the class of WEAK INTERACTIONS (of which K decay was one) obeyed the hitherto sanctified symmetry of SPACE INVERSION. Their suggestion led to a brilliant experiment by C. S. Wu and collaborators which showed that the beta decay of Co^{60} violated this symmetry (left/right PARITY). Specifically the experiment showed that the cobalt nucleus whose spin points in the UP direction emits more electrons in the 'DOWN' direction than in the UP. An observer looking in an inverted frame of reference would see more electrons in the UP direction, though the Spin of the nucleus is still UP (Spin is an Axial Vector and does not reverse).

This discovery of violation of parity in beta decay brought new attention to the neutrino. If its mass was exactly zero, it would always travel at the velocity of light like the photon. Suppose now the neutrino created in a decay is 'left handed', i.e. its spin and its motion were oppositely directed. Then that neutrino will appear left handed to all observers no matter how fast they move because they can never move faster than the neutrino to make it seem go backward. In other words, left handedness of a neutrino COULD be an absolute property. Indeed M Goldhaber, L Grodzins and A Sunyar performed an experiment that did verify that the neutrino emitted in beta decay is almost always left handed.

6. THE TWO NEUTRINO EXPERIMENT:

Interest now surged in looking afresh at reactions in which a neutrino is involved. Recall the muon decay:

$$\mu \longrightarrow e + \nu + \bar{\nu} \quad (6)$$

There is, on the face of it nothing which prevents the muon from decaying thus:

$$\mu \longrightarrow e + \text{g} - (7)$$

Experimentally, this reaction seems forbidden! This suggested that some selection rule was in operation. The commonly observed muon decay (6) in which a left handed neutrino and a right handed anti neutrino appear, does not suggest anything to forbid (7); T.D. Lee and C N Yang had an idea that the and ? that appear in (6) may not be antiparticles of each other.

One way of testing this was to look specifically at reactions produced by neutrinos which requires a BEAM of neutrinos. By early 1960, this became a possibility at the Brookhaven National Laboratory. Pion beams were already available copiously and charged pions could be 'trained' by suitable electromagnetic methods to form a long 'pipe' of fast pions in which some will decay:

$$\text{P} \longrightarrow \mu + \nu$$

The decay products will essentially also be carried forward as a beam. Now a huge shield of some 12m of steel ensured that all particles except the neutrino are 'stopped' and what emerged was a beam of neutrinos associated with the muon. The neutrinos then go through a detector of some 10 tons so that a small fraction of them interact with the detector material which detects the charged products produced. It was found that the muon associated neutrinos only produce muons, almost never an electron showing that the muon associated neutrino is distinct from an electron associated neutrino.

In 1975, yet another 'heavy' electron (like the muon, but even more massive) was discovered (τ) and with its associated neutrinos. Thus the family of weakly interacting particles called LEPTONS form three pairs: (e, ν_e), (μ, ν_μ) and (τ, μ_τ)

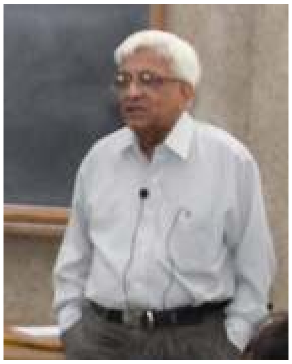
7. NEUTRINO OSCILLATIONS:

But the neutrino puzzles had not abated! It was well established that solar energy was due to nuclear fusion which releases neutrinos (ν_e). The two important sequences of reactions are the proton-proton (p-p) cycle and the Carbon-Nitrogen-Oxygen (CNO) cycle. Their relative proportion in solar energy production is highly sensitive to the interior temperature of the sun and it is only the neutrinos from the CNO cycle that are detectable and that with some difficulty. Still, it has become increasingly clear that the flux of neutrinos (ν_e) is much less than expected. So what happens to the neutrinos on their way from the Sun to the Earth?

The wheel has come a full circle! If massless neutrinos had a fascination for theorists in the years following the discovery of parity violation, now what the 'doctor ordered' was a tiny mass for the neutrinos - and that had never been excluded by the data hitherto. A little mass allows an odd quantum phenomenon called MIXING of neutrinos. The idea is that the neutrino produced in the Sun is not a neutrino with a specific mass but rather it is a quantum superposition of neutrino mass states. As the neutrinos travel away from the Sun, they slowly change their 'flavour' and some metamorphose to muon or tau type neutrinos which is why they escape detection in the experiments on earth. It seems well established now that not all neutrinos are massless. In the near future quite delicate experiments are planned to study these neutrino OSCILLATIONS (from one type to other types). I shall mention two such planned experiments. An India based neutrino observatory (INO) has been established in Theni district in Tamil Nadu. A feature is a massive detector, some 50,000 tons of magnetized iron said to be the largest yet. In the US, there is planned a 'Long Baseline Neutrino Experiment (LBNE). Here, a beam of neutrinos produced in FERMILAB, Illinois will go through some 800 miles inside the earth to reach HOMESTEAD mine in South Dakaota where suitable detectors will study neutrino induced reactions. Among the aims of these huge experiments is to make a precise determination of the masses (or mass differences) of the neutrinos and other parameters involved in neutrinos oscillations. Even more ambitious is the study of some fundamental questions as, for example, why there is so little of antimatter in the universe which has so much matter.

In less than a century, emerging from a nebulous particle to a status of a prime tool to study Cosmological problems has indeed been a remarkable tale of the neutrino.

Prof S Lokanathan has been a source of inspiration for all our educational programs; he taught the undergraduate students which eventually transformed in to REAP.



Moon in the class room - II

- B S Shylaja

(continued from the previous issue)

The concept of atmospheric refraction can be understood by the observed difference in the time of moonrise and set. The distortions in the shape of the moon, the color also are discussed in the classroom.

The moon comes very handy in explaining the phenomenon of twinkling and seeing. It is easy to project the refracted rays back on to the moon. The planets do not offer this opportunity as and when required for a demonstration and demand a telescope.

One of the amateur astronomers Mr. Dilip Kumar has taken a sequence of photographs of the moon through December, 1996. The excellent quality of these images inspired many students to take up astro-photography. I used this sequence for a totally different purpose.

The students were given copies of the photographs and asked to arrange them in the order of phase. That automatically attracted them to the different features on the moon. The fact that the moon shows the same side to us was easily understood by these pictures. One particular student measured the size of the moon with a simple coin and scale arrangement to demonstrate that the moon's apparent big size near the horizon is only an illusion.

The second exercise was to measure the diameters of the disc of the moon on these images. They were taken by the same camera set up and hence the diameter ought to have remained constant throughout the month. But it did not. How would one explain this?

They continued the calculation of the distance to the moon based on the angular size. The fact that moon orbits in an elliptical path was immediately deduced.

One of the lengthiest discussions was related to the old moon in the bowl of the new moon. That took us to the days of Galileo. Students very eagerly repeated the calculations of the height of the mountain.

The hype about the full moon of December, 1999, when the full moon coincided with its perigee and the winter solstice of the sun, provided an opportunity for calculating the differential gravitational forces in the simplest possible way. Taking the average distance to the moon as 384,000 kms and the perigee and the apogee distances from the almanac, they calculated the differential gravitational force. Their joy knew no bounds when their graph almost matched with the one provided in that issue of Sky and Telescope.

Most of the children here would have never visited a beach and therefore, the phenomenon of tides also needs to be explained. The question on the duration between the successive high tides, that it is more than 12 hours, can be understood in the class room and not on the beach for these students.

It was necessary to have different models to explain every concept. Thus we have rugged and hand operated models

1 to explain the phases of the moon,

2. that the rotation and revolution of the moon have same period.

3. that the moon shows the same side to the earth,

4. that eclipses do not take place every month.

(We have not accepted a challenge to combine all these in to one, which amounts to copying the nature with all its complexity.)

There is a particular advantage in teaching in a society, which follows a lunar calendar. Every student is conscious of "his" or "her" star - corresponding to his time of birth. The 27 star system is followed here to locate the moon. Quite obviously, these 27 belong to the zodiac. Therefore, the questions on the first session were, "are there only 27 stars in the sky?", "my star is Mrigasira (lambda Orionis); how come I am a Leo?" "Why there is no zodiacal constellation for the pole star?" and so on.

Although these are quite confusing, it helped the students in a completely different way. The name of the month in the lunar calendar gives a clue to the name of the star itself. For example, Spica is called Chitra and the month (March - April) when the full moon is near this star is called Chaitra. The month when the full moon is near Antares (called Jyeshta) is also called Jyeshta. The full moon was observed for all the 12 months. The star positions were noted to identify the 12 zodiacal constellations. Interestingly, some stars are not in the zodiacal constellations. The case of lambda Orionis is the best example. That set them in to the discussion on the meaning of the ecliptic and the need for a specific width of the zodiacal belt. The tilt of the moon's orbit by about 5 degrees could then be explained by simply following the moon's path thorough the month. I gave them an equatorial sky map. They plotted the position of the moon on it, found that it crosses the ecliptic twice. These points of intersection (the nodes) are familiar to them by the mythological story on eclipse. They are called Rahu and Ketu. The students were thrilled to have identified these fictitious “planets”.

As a continuation of the exercise I asked them to plot the position of the moon for the month of July, 1999. The moon crossed the ecliptic exactly on the two new moon days and the full moon day – making it a special month with three eclipses!

The prediction of eclipses and observations were another thrilling experience for the senior students. Some were content with just one eclipse; but there were a handful who continued for a few more. They naturally were puzzled by the colour of the eclipsed moon – sometimes it was copper and sometimes dark brown. No wonder they were heading for the conclusions deduced almost 100 years ago. The volcanic dust does the mischief.

The moon thus entered the class room in the pretext of astronomy, but swam through sessions of physics, mathematics and geography. It was a welcome entity everywhere!

Science In Action (SIA) : How and Why?

- H.R. Madhusudan

Let us go back in time by twenty –two years. Computers were beginning to make their presence felt in Banks and other industrial applications. Internet was yet to become a public utility that it has now become. Free email services such as Hotmail, Yahoo Mail or G- Mail were all well below the horizon. The role of computers in education (and, science in particular) was being debated. Today, a debate on this issue sounds irrelevant. Computer-based simulations and animations are the commonest ways to bring scientific phenomena found in nature right into the class room - at the click of a mouse button. We now feel, and justifiably so, that computers and internet armed with powerful search engines are enough to put life into science teaching / learning – to see phenomena in action, although virtually. Twenty-two years ago, putting life into a science class meant carrying interesting demonstrations into the classroom. THAT was the only way to carry the phenomena into the class room. For various reasons there were very few of those. It is against this background that Science In Action was conceptualized and shaped by Prof C V Vishveshwara, the founding-Director of JNP in 1993. An exhibition of some of the wonderful experiments drawn from various scientific disciplines was held at JNP in that year. Research institutes such as RRI, ISRO, IIA and IISc contributed experiments that brought several scientific

Scientists interacting with students during SIA exhibitions

concepts alive. Analysis of Stress induced in photoelastic material using a pair of polarizers, demonstration of self-actuating antenna in space, Nitinol Alloy that 'somehow remember' shape imparted to it at a specific temperature, Functioning of Heat Pipes that transport heat in satellites, liquid crystals that change to specific colours with temperature, periodic reversal of the direction of flow of salt solution into water and vice versa were some of them. The working experiments, as opposed to static illustrations like pictures, charts and thermocole models, establish connection with the observer immediately. The sight of light bending in a gradient refractive index medium, for example, is such a strong stimulus that children (and adults) would remember it for a long time.

Over the last twenty-two years, JNP has been conducting '*Science In Action*' exhibition, setting up about twenty-five working experiments every year, illustrating important concepts that are discussed in standard syllabi of school / college curriculum. Beginning in 1998, we have been inviting experiments exclusively from schools to be set up at SIA. Select experiments are demonstrated and explained over three days by the students who set them up. In addition to this, JNP hosts another edition of SIA each year by setting up experiments of its own along with a few contributed by various research institutes. Student volunteers are taken from different schools and all the experiments are demonstrated and discussed in detail. They, in turn, demonstrate the experiments to the visiting students. Usually, about 6000 people, mostly students, visit SIA. The description of the experiments in Kannada and English is available on JNP's website. This has enabled us to reach out to larger audience. Several schools and colleges use it as a resource for their science exhibitions and teachers use it for class room teaching activities. In recent times there is a fairly good number of NGOs and motivated individuals who work with schools in rural areas and special schools for the underprivileged children. They also make use of the resource generated through SIA. The working models and experiments are borrowed by several schools every year for their exhibitions. These experiments, presented in an informal atmosphere such as in an exhibition, provide rich learning experience to students and teachers making the subject an endearing one. Some of the experiments initially set up for SIA have been scaled up and set up in our Science Park. These lend a greater life span for the exhibits and attract tens of thousands of students, teachers and the informed public. In summary, it is gratifying to note that SIA has been serving a useful resource generating programme in presenting and perceiving science as it should be – IN ACTION.

Edited & Published by
The Director
JAWAHARLAL NEHRU PLANETARIUM
Sri T. Chowdaiah Road, High Grounds, Bengaluru-560 001
Ph: 080-22379725, 22266084
E-mail: info@taralaya.org Website: www.taralaya.org