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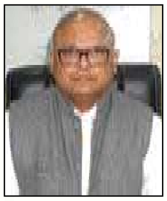
International Year of Light 2015

Chaos: an astounding science

... think scientifically, act scientifically... think scientifically, act scientifically... think scientifically, act...

How very clear! Truly Inspiring



Dr. R. Gopichandran

The Inspiring Australia initiative is designed for robust outreach and engagement with citizens. The principal focus is benefits of science that is expected to infuse a spirit of innovation. The objective is to become a "scientifically engaged community and a technologically skilled workforce". Science communicators in India too will be able to resonate with this call. I present a snapshot of the contents and urge you to assimilate the larger picture yourself by accessing the relevant document from the source indicated below[1]. Please also take note of the variety of stakeholders/enablers and the public policy interface they have highlighted.

We in India will be able to take away some important messages from the initiative. First, a "Framework of Principles" highlights quality in science communication and proposes to harmonise approaches and advance engagement. This is well defined on the basis of six features. Secondly, of these six, I wish to especially emphasise relevance and credibility. In the Indian context, relevance as referred in the Inspiring Australia initiative should also be about being state of the art in content and communication and not antiquated. Credibility applies as much to the profile of the communicator as to the quality of science that is being communicated. Credibility through good behaviour should be about acknowledging the wisdom of others to foster camaraderie. Communicators cannot be seen as self-perpetuating; especially when varied culture and related wisdom across India's landscape embellishes heterogeneity. These are in addition to such features of science being communicated as "credible, defensible and accurate". Importantly, I am reminded of the adage "those who live in glass houses should not throw stones at others". Communicators should also be known for their spirit of inclusiveness. Finally, it is important to align communication with policies. Science communication need not be in a vacuum of sorts that speaks only of principles of science and its open-endedness.

Going ahead of these learnings I wish to invite your attention to a classic publication of Time Inc. NY[2] I recently laid my hands on. It is 560 pages of sheer joy of reading a collection of great writing. Communicators will derive invaluable lessons on the art of communication through writings that harmonise information with wisdom. Some of them are about the first mission to the Moon, heart transplant, and Einstein's take on science and politics. I am sure you too will agree with me when you get to read through the publication cited. Sincere thanks to Prof. Shyam Asolekar of the Centre for Environmental Sciences and Engineering at IIT Bombay who gave a complementing insight. He taught me that Expertise = Precision + Speed. These learnings are truly inspiring.

References

1. Framework of Principles for Science Communication Initiatives http://www.industry.gov.au/Science/InspiringAustralia/Documents/National%20Framework%20of%20Principles.pdf _accessed on 13 November 2015.
2. Christopher Porterfield (Ed) 2008. *TIME 85 Years of Great Writing*. 560p. Time Books, Time Inc. NY.

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Fifty Years of Mobile Science Exhibition in India

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Birla Industrial and Technological Museum or BITM, the first major science museum of the country was established in Calcutta (now Kolkata) in 1959. An avant-garde institution, BITM carried the message of science beyond its four walls through a travelling science exhibition which it had launched in 1965. By late 1966, the museum had introduced the 'Mobile Science Exhibition', mounted on a specially designed bus called 'museobus'. Currently 25 science museums and science centres, located in 17 States and two Union Territories, operate mobile science exhibitions throughout the year for the benefit of rural and suburban students. Importantly, 21 of these institutions are units of National Council of Science Museums (NCSM). This article is a brief historical account of this exemplary outreach activity of science museums and science centres in India.

Inauguration of Mobile Science Museum on 17 November 1965

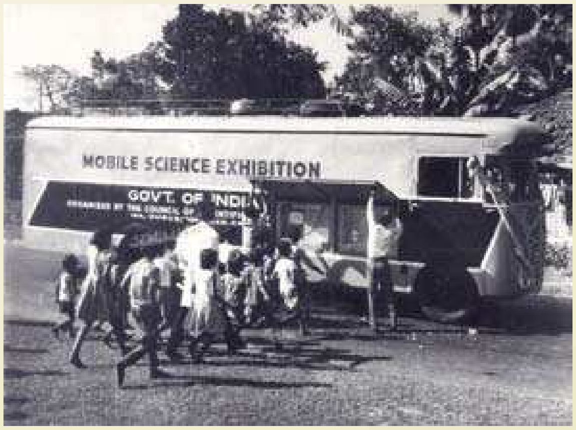
Mobile Science Museum

In 1950s, UNESCO had developed five travelling science exhibitions and two of those, with the themes 'Our senses and the knowledge of the world' and 'Energy and its transformation', were exhibited in some Indian cities. Travelling science exhibition was also a significant activity of the Polytechnic Museum of Moscow in the erstwhile Soviet Union since late 1950s. Virginia Museum of Fine Arts in Richmond, USA had also launched a travelling exhibition of paintings called Artmoblie in 1953. But there was no record of indigenously developed travelling science exhibitions in India prior to 1965, when Saroj Ghose, Curator-in-charge of BITM felt the need to take scientific exhibits beyond its four walls to create scientific temper in the community. BITM was then functioning under the Council of Scientific and Industrial Research (CSIR). In March 1965, Ghose got an opportunity to narrate his concept of Mobile Science Museum to Dr Hussain Jaheer, the then Director General, CSIR in New Delhi. Dr Jaheer heard him patiently and uttered just two words 'go ahead'. The CSIR then allotted additional fund and gave full support to the project.

It took six months (May-Oct 1965) for Saroj Ghose and his team in BITM to design and fabricate the exhibits of a travelling exhibition on 'Our familiar electricity'. The exhibits were designed by Saroj Ghose; portable stands were designed by Shasanka Sekhar Ghosh; artwork was done by R.C. Chandra; engineering drawings were prepared by Debabrata Basu; fabrication was done by Ashok Dutta and S.B. Shome in the Electrical Workshop. The exhibition called Mobile Science Museum (MSM) was mounted on stands which could be easily set up in a hall, dismantled and transported by truck.

On 17 November 1965, the mobile science museum was inaugurated by Prafulla Chandra Sen, then Chief Minister of West Bengal, at Narendrapur Ramakrishna Mission Ashram School, Narendrapur, about 17 kilometres away from BITM.

The unit on 'Our familiar electricity' with 30 exhibits attempted to make school children and general public familiar with electricity and its use in daily life. The working models showed operation of telephone receiver, electric lamp, electric heater, electric fan, radio receiver, and so on. Written explanation of individual exhibits was given in simple Bengali. The exhibition at Ramakrishna Mission Ashram School was on display for five days. Dilip K. Pathak, Guide Lecturer from BITM coordinated the activities in the school. During 1966, the same unit was exhibited in 25 schools in the districts of 24 Parganas, Howrah, Hooghly, and Nadia in West Bengal.



First museobus was introduced in 1966

Mobile Science Exhibition

In 1966, BITM changed the title of travelling exhibition from 'Mobile Science Museum' to 'Mobile Science Exhibition'. It was realised by BITM authorities that the mobile unit was not carrying any scientific artefact, typical of a museum, but was showing didactic and working exhibits. So the term 'exhibition' looked more appropriate than 'museum'.

The authorities of BITM also felt operational difficulties in running the mobile science museum as designed in 1965. It was a cumbersome and laborious process to pack, load, unload, unpack and set up display stands and exhibits at each exhibition site. Solution to this problem came in mid 1966 with the introduction of the 'museobus', which was conceptualised by Saroj Ghose and designed by Shasanka Sekhar Ghosh.

Venus, the first Indian 'museobus' was a specially designed structure on standard truck chassis that mounted a set of 28 exhibit cabinets of standard size in four rows, two facing outside and two facing inside. So, 14 (7x2) exhibits were placed on the floor of the bus facing the outside at eye level for visitors outside the bus and the remaining 14 (7x2) were placed on the upper level for visitors standing inside the bus. The museobus was fabricated by National Motor Works, Calcutta.

The first 'museobus' carrying working and participatory science exhibits on the theme 'Transformation of energy' was inaugurated on 27 December 1966 in Barsul Vijnan Mandir near Shaktigarh in Bardhaman district of West Bengal.

Sixty plus units in fifty years

During the period between 1965 and 1976, while functioning under CSIR, BITM had developed eight mobile science exhibition units. In 1978, at the time of formation of the National Council of Science Museums (NCSM), only six museobuses were in operation. BITM with three museobuses exhibited five units, namely, 'Transformation of energy', 'Popular science', 'Light and sight', 'Water – the fountain of life', and 'Science of motion'. Visvesvaraya Industrial and Technological Museum in Bangalore then had two museobuses to exhibit units on 'The planet we live In', 'Water – the fountain of life', and 'Popular science'. Nehru Science Centre, Mumbai had one museobus with an exhibition unit on 'Man must measure'.

Science Museums and Science Centres

Looking into the Earth to unravel nature

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It was around 4 am on a wintery early morning. People were deep asleep cuddling up warm under their blankets as cold winds were blowing outside. Suddenly there was a roaring sound and soon cupboards, beds, tables, chairs in the houses were shaking violently. It lasted just for a few seconds. But, mayhem ensued. A killer earthquake had hit the small township next to Koyna dam in Maharashtra with a magnitude of 6.3 on the Richter scale.

Second ICDP International Workshop at Koyna, May 16-18, 2014

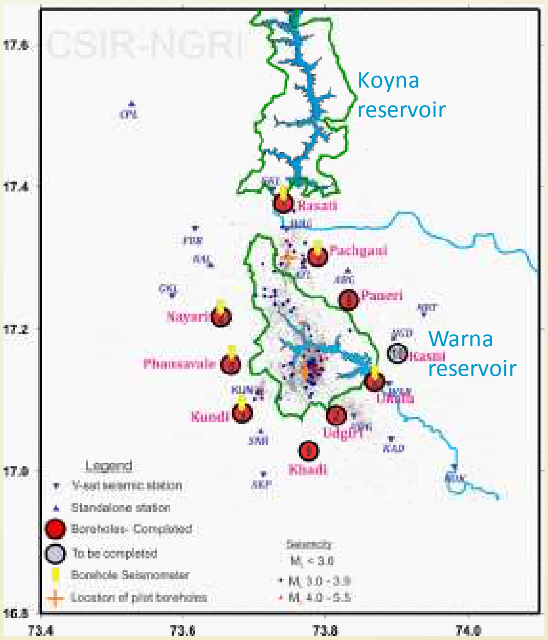
Approximately 80% of the houses in the township were reduced to rubble. In addition, five neighbouring communities lost every single home. Most of the villages were small. For example, there were only 53 houses in the village of Nanegaon; all 53 were destroyed. Housing damage and destruction were scattered throughout 50 villages, leaving some 5,000 people homeless in the region. For many of these people, their houses and the surrounding land represented everything they owned. For some, the evacuation that ensued during the emergency evacuation phase was as devastating psychologically as the actual shaking was physically.

The quake occurred on 11 December 1967 and since then life has not been the same for the people living in the picturesque area. The earth keeps shaking every now and then. Over the past nearly five decades, there have been over 20 quakes of magnitude 5 and above, and about 200 of magnitude 4. Besides, several thousand smaller quakes have been experienced..

The frequency of the tremblors in the area has increased significantly since 1990s with the commissioning of another reservoir called Warna nearby in 1993. All this is in contrast to no earthquake recorded in that area till 1962, when the dam was commissioned.

In fact, Koyna today occupies an important place in the global map of earthquakes: a must-visit site for seismologists across the world, particularly for those who specialise on seismicity triggered by water reservoirs.

A unique feature of the seismicity in Koyna is that the earthquakes are confined to an area spread over just 20 km by 30 km. Also, the quakes generally emanate within a depth of 10 km only and most of it within the top 7 km of the Earth's crust.



Koyna seismicity Aug 2005 – mid-2015

Studies over the years have clearly proved that it is a case of reservoir-triggered seismicity or RTS. But not much beyond that is known since the studies had to depend on data collected on surface alone. For instance, not enough data is available to examine issues such as fluid pressure regime underground in the area and its variations and correspondence with the occurrence of the quakes.

These gaps in knowledge could probably get filled up soon as the Ministry of Earth Sciences of Government of India has recently launched a programme to investigate the inside of the Earth in the area by drilling deep boreholes and installing equipment at different levels underground to observe what happens in the Earth's crust before, during and after an earthquake strike.

The investigation is being conducted in collaboration with Intercontinental Scientific Drilling Programme (ICDP), an international consortium that was formed in 1996 to promote high-precision scientific drilling to help the global community have a better understanding of natural resources and natural hazards across the world.

Scientists would seek answers to questions relating to earthquakes both in general and specific to reservoir-triggered seismicity. They will try, among other things, to find out what kind of physical or chemical changes take place in the rocks underground during earthquakes as also how temperatures change and whether there is melting of rocks.

After a preliminary survey during which 10 boreholes were drilled for different depths up to a maximum of 1.5 km, a team of scientists have identified one site for further drilling. The selected site lies just about 100 m from where most of the recent quakes have been emanating.

National Brainstorming Workshop Koyna, March 19-20, 2013

Earlier, a seismic network of 15 sensors operating in the region for six years had helped the scientists to precisely locate the area where the earthquakes were occurring.

According to Dr. Shailesh Nayak, who recently retired as Secretary, Ministry of Earth Sciences and is presently Distinguished Scientists in the Ministry of Earth Sciences, the site has been selected as it was the closest to fault zone, which runs vertically down. "We wanted to be as close to the fault zone as possible so that we get to analyse the seismic waves at its purest form. We cannot obviously drill along the fault zone as the rocks there would be broken and it would not be possible to drill the boreholes. Luckily we were able to identify a site which was not too near nor too far".

Two boreholes are planned to be drilled. To begin with, the drills would be bored up to a depth of 3.5 km. "Earthquakes have been emanating from a depth of 3 to 7 km. We hope to get adequate data at a depth of 3.5 km itself. However, if we need to go further down, we can always do it later".

Of the two boreholes, one will be closed after installation of various equipment at different depths, while the second one will remain open so that it could be drilled further if needed. The second bore will be used for conducting experiments that do not require a closed environment. Among other things, seismometers, temperature loggers, strain meters (to measure deformities in the rock) and some instruments to measure physical parameters like rock density would be placed all along the closed borehole.

The drilling of the two boreholes, is expected to be technically a very challenging task, as the terrain is made of solid rocks and it would be for the first time such a task is being undertaken in India. "If all goes well, the boreholes should be ready by May 2016", Dr. Nayak said.

Such experiments are being conducted at several other places in the world including one in California, USA to study the San Andreas Fault at the interjection of Pacific and North American tectonic plates. But, the Koyna-Warna deep borehole project would be the first of its kind to directly investigate earthquakes in a stable continental crust. Dr. Nayak expressed the hope that the experiment would not only help understand the reservoir-triggered seismicity in the Koyna-Warna region in greater depth, but also earthquakes in general.

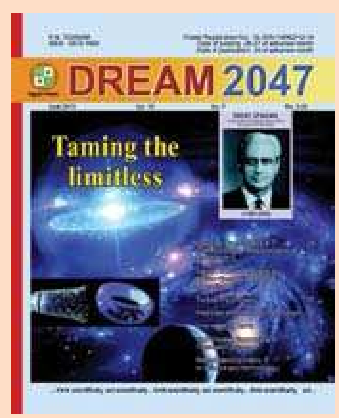
The experiments are also expected to throw more light on the subject of Deccan volcanism. Scientists have found that a series of massive volcanic eruptions occurred in the Deccan region some 66 million years ago, leading to one of the world's largest lava flows. The episode, spread over several hundred years at the end of Cretaceous period, is believed to have wreaked havoc on the global climate leading to the mass extinction of dinosaurs.

The original area covered by the lava flows is estimated to have been as large as 1.5 million sq. km – approximately half the size of modern India. The present area of directly observable lava flows is, however, far less though still a massive area of around 5,12,000 sq. km. In addition, the experiments are expected to help in further understanding of the geothermal potential of the West Coast Belt as well as geothermal record of climate change in the region.

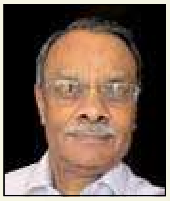
Sixty thermal water springs occur at 18 localities in the West Coast hot spring belt. This belt extends along the West Coast for a distance of about 350 km from Koknere, north of Mumbai, to Rajapur in the south, with an average width of 20 km. This belt falls in Thane, Raigad and Ratnagiri districts of Maharashtra. The eastern boundary is marked by mighty scraps of Sahyadri Mountain commonly known as Western Ghats while its western margin is marked by coastline of the Indian Ocean.

The Ministry of Earth Sciences has planned for a long-term experiment and has set up a separate Borehole Geophysics Research Laboratory at Karad about 65 km from the drill site. Could the experiments at Koyna also lead to development of a mechanism for forecasting earthquakes? Dr. Nayak's short answer: "The borehole drilling investigation is an open-ended exercise. We don't know what it will be the outcome. Let's hope for the best".

P. Sunderarajan, is a freelance journalist. He was earlier with India's leading national English daily ``The Hindu" for over 35 years covering science and technology and other subjects till he retired in April this year as Deputy Editor.



Neutrino: The Chameleon Particle



Biman Basu
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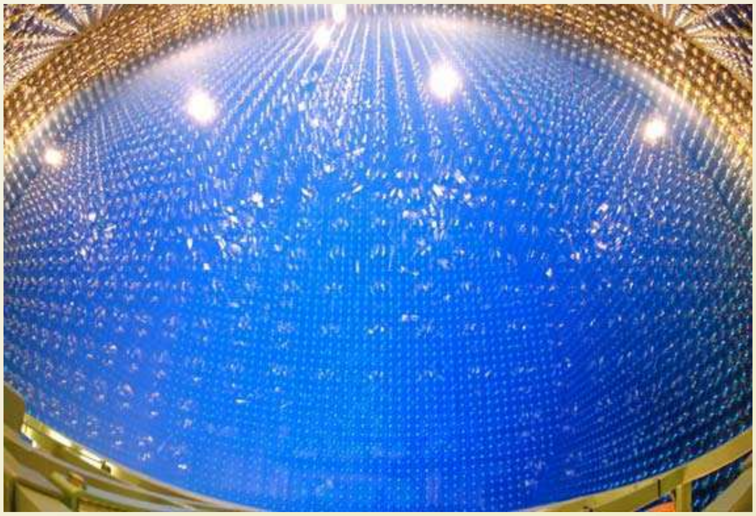
Neutrinos, also known as "Nature's ghost particles" are subatomic particles produced by the decay of radioactive elements. They lack an electric charge and till recently it was not known if they possess mass. After photons – the particles of light – neutrinos are the most numerous in the entire cosmos. Since they carry no charge and hardly any mass, they can pass through almost everything without interacting. According to astrophysicists, of all high-energy particles, only weakly interacting neutrinos can directly convey astronomical information from the edge of the universe – and from deep inside the most cataclysmic high-energy processes. This is because neutrinos are copiously produced in high-energy collisions, they travel essentially at the speed of light, and are unaffected by magnetic fields. So they remain unabsorbed and without changing as they travel over trillions of kilometres from the edge of the universe. Hardly anything can stop them passing; neutrinos are nature's most elusive elementary particles. Closer to Earth neutrinos are also created in reactions between cosmic radiation and the Earth's atmosphere. Others are produced in nuclear reactions inside the Sun.

(Left to right): Takaaki Kajita and Arthur B. McDonald

It was the Austrian-born Swiss theoretical physicist Wolfgang Pauli who first postulated the existence of neutrino in December 1930 to explain why the electrons in beta decay were not emitted with the full reaction energy of the nuclear transition. Pauli theorised that an undetected particle was carrying away the observed difference between the energy and angular momentum of the initial and final particles. Italian physicist Enrico Fermi called the particle a 'neutrino' and developed a theory of beta decay based on it, but it was not until 1956 that the particle was experimentally observed. In that year, Clyde Cowan, Frederick Reines, F.B. Harrison, H.W. Kruse, and A.D. McGuire published the article 'Detection of the free neutrino: a confirmation' in the journal *Science*. Reines shared the 1995 Nobel Prize for this work.

A majority of the neutrinos floating around in the universe are believed to have been produced around 15 billion years ago, soon after the birth of the universe. Since then, the universe has been expanding and cooling, and neutrinos have just kept on going. According to cosmologists, theoretically, there are now so many neutrinos that they constitute a cosmic background radiation whose temperature is 1.9 kelvins (–271.2 degree Celsius). More neutrinos are constantly being produced from nuclear power stations, particle accelerators, general atmospheric phenomena, and during the births, collisions, and deaths of stars, particularly the explosions of supernovae. In fact, neutrinos are omnipresent in Nature. Every second, tens of billions of them "pass through every square centimetre of our bodies without us ever noticing." Despite being plentiful, however, neutrinos are extremely difficult to detect.

The feeble interaction of neutrinos with matter makes them uniquely valuable as astronomical messengers. Unlike photons or charged particles that are either absorbed or deflected by matter or magnetic field, neutrinos can emerge from deep inside their sources and travel across the universe without interference and change. They are not absorbed by intervening matter and are not deflected by interstellar magnetic fields. However, this same trait makes cosmic neutrinos extremely difficult to detect and extremely large detectors are required to find them in sufficient numbers to trace their origin.



The walls of Super-Kamiokande detector are lined with more than 10,000 sensitive photomultipliers, which distinguish between muon neutrinos and electron neutrinos. The bottom of the detector is filled with ultra-pure water (blue). Golden photomultipliers cover the walls.

Neutrinos interact only by the weak force or interaction, which is one of the four fundamental forces that govern all

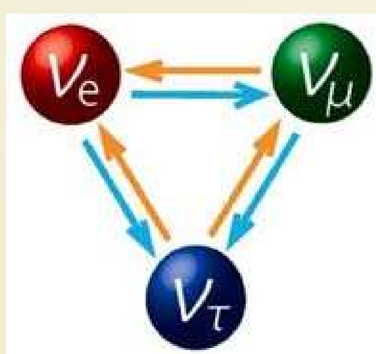
The Sudbury Neutrino Observatory in Canada is a scientific masterpiece (here seen during construction). Designed to detect solar neutrinos, it is a spherical tank measuring 12.2 metres in diameter and is located 2 kilometres beneath the Earth's surface. It is filled with heavy water.

matter in the universe (the other three are gravity, electromagnetism, and the strong interaction). While the other forces or interactions hold things together, the weak force plays a greater role in things falling apart, or decaying, as happens with radioactive elements. The weak force is stronger than gravity, but it is only effective at very short distances.

Neutrinos come in three 'flavours', each type relating to a charged particle (lepton), namely electron, muon, and tau. But they show a unique property known as 'neutrino oscillation', which is a quantum mechanical phenomenon whereby a neutrino created with a specific flavour (electron, muon, or tau) can later be measured to have a different flavour. In other words, neutrinos are chameleon-like particles, switching identities in an instant. The Nobel Prize in Physics for 2015 has been awarded jointly to two scientists – Takaaki Kajita and Arthur McDonald – for their research that confirmed that neutron do change their identity. The discovery has led to the far-reaching conclusion that neutrinos must have some mass, however small. For more than half a century, neutrinos were believed to be massless.

Although very difficult to detect, neutrinos have been detected using massive detectors. The most successful technique of detecting neutrinos makes use of a phenomenon called 'Cherenkov radiation' occasionally produced by the passage of neutrinos through large masses of liquid in the detector, three of which are in operation.

The Super-Kamiokande, or Super-K for short, is a neutrino observatory in Japan. The observatory was designed to study solar neutrinos, study atmospheric neutrinos, search for proton decay, and detect neutrinos from a supernova anywhere in our galaxy. Located 1,000 metres underground, it consists of 50,000 tons of highly purified water surrounded by about 11,000 photomultiplier tubes. The cylindrical structure is 40 metres tall and 40 metres across. A neutrino interaction with the electrons or nuclei of water occasionally produces a particle that moves faster than the speed of light in water (although, of course, slower than the speed of light in vacuum). This creates a flash of light due to Cherenkov radiation, which is the optical equivalent to a sonic boom caused by objects moving faster than sound through air. The flash can be detected by the photomultipliers. The distinct pattern of this flash provides information on the direction and flavour of the incoming neutrino. In 1998, Kajita had discovered that neutrinos from the atmosphere switch between two identities on their way to the Super-K detector. This discovery helped prove the existence of neutrino oscillation and neutrino mass.



Neutrinos a quantum mechanical phenomenon whereby a neutrino created with a specific flavour can later be measured to have a different flavour.

The Sudbury Neutrino Observatory (SNO) is a neutrino observatory located at 2,100 metres underground in a mine in Sudbury, Ontario, Canada. The detector was designed to detect solar neutrinos through their interactions with a large tank of heavy water. The detector was turned on in May 1999, and was turned off on in November 2006. While new data is no longer being taken, the SNO collaboration will continue to analyse the data collected during that period for the next several years. Working with the SNO, McDonald demonstrated that the neutrinos from the Sun were not disappearing on their way to Earth as believed earlier. Instead they were captured with a different identity when arriving at the SNO. This observation also corroborated neutron oscillation.

The IceCube project in Antarctica is the world's largest neutrino detector that uses a cubic kilometre of ice instead of water. To facilitate this it is located in Antarctica at the South Pole, the only place to find a chunk of ice big enough! IceCube searches for neutrinos from the most violent astrophysical sources: events like exploding stars, gamma-ray bursts, and cataclysmic phenomena involving black holes and neutron stars.

The work of Takaaki Kajita and Arthur McDonald has resolved a long-standing mystery about the nature of the elusive neutrino. Now the experiments continue and intense activity is underway worldwide in order to capture neutrinos and examine their properties more closely to understand them better. New discoveries about their deepest secrets are expected to change our current understanding of the history, structure and future fate of the universe.