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Prof. B.V. Sreekantan delivering the 5th JRD Tata Public Lecture on Aug. 18th, 2005 at the Homi Bhabha Auditorium. The lecture has been published. Please see http://www.ias.ac.in/currsci/apr102006/1012.pdf

Left-bottom and top: Exhibition of "**Scientific Art - A Creative Interaction"** by Sukant Saran in the foyer of Homi Bhabha Auditorium. Inaugurated by the Director of TIFR, Prof. S. Bhattacharya

SCIENCE AND THE HUMAN PREDICAMENT

by

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A public lecture on December 21st 2005 in the Homi Bhabha Auditorium.

The past century in science

This year is the centenary of Albert Einstein's "Annus Mirabilis", 1905. It may therefore be worthwhile to remind ourselves very selectively of where we were in physics in particular, and in science in general, a century ago, and what major advances have occurred since then. On the experimental side, the previous decade had seen the discoveries of X-rays, the electron and radioactivity. But around 1905 doubts were still expressed about the existence and reality of atoms. At the other end of the scale, even upto 1919, it was believed that the universe consisted of our Milky Way galaxy alone. The processes behind energy production in the sun and other stars were unknown, neither were there concepts and language to talk meaningfully about cosmology. It was still thought that the ether was necessary as a carrier of electromagnetic waves. The origins of spectra and of the laws of spectroscopy were unclear, as also the basic principles of chemistry. The Darwinian theory of evolution had been formulated in 1859 but the underlying mechanisms were unknown. The principles of genetics found by Gregor Mendel in 1865 had been forgotten, awaiting rediscovery by Hugo de Vries and others in 1900.

Today, even school children are aware of the enormous progress that has been made on all these fronts. Limiting oneself to the most major advances, one should mention the special and the general theories of relativity from 1905 and 1915 respectively, followed by quantum mechanics in 1925-26. This was preceded of course by the old quantum theory led by Planck, Einstein and Bohr. With the advent of special relativity, the ether was finally given up and electromagnetic radiation became an irreducible constituent of nature. The secrets behind spectroscopy, the periodic table of the elements, and the theoretical underpinnings of chemistry, were all revealed by quantum theory. As time went on, atomic, molecular, nuclear and elementary particle physics, as well as all processes involving radiation, became amenable to analysis. These led in turn to the whole domain of astrophysics, the understanding of stellar structure and evolution. Experimental discoveries resulted in a reappraisal of the size and content of the universe. Thus our Milky Way is only one of some one hundred billion galaxies, each with as many stars. From general relativity came the conceptual basis and tools for the subject of cosmology.

In the life sciences, the greatest advances have been in the field of genetics at the molecular level, leading to the material and mechanism on which Darwinian evolution works. The crowning achievement was the 1953 discovery of the structure of the genetic material, DNA, by Watson and Crick. Here the astonishing earlier work by Avery, Macleod and McCarty should also be mentioned. The upshot has been the realization of the great unity in all forms of life at the molecular level.

In this very brief listing, let me add Claude Shannon's classical theory of information from 1948 – a really beautiful mathematical analysis showing how to measure information and its transmission quantitatively. This has been the foundation on which the later information revolution has grown.

As far as practical applications of physics are concerned, we can say that in the first half of the 20th century it was mainly the exploitation of classical physics, for example in communication and transport. The fruits of quantum mechanics have come during the second half of the century, through the transistor revolution, the computer age, lasers and many medical applications.

Human knowledge – Kantian philosophy

I would now like to take you a little further back in time – to about two centuries ago – and trace the development of certain ideas in the form of a story. Towards the close of the 18th century, the physical principles and methods established by Galileo and Newton had been repeatedly and remarkably successful in explaining many phenomena. Apart from the initial domain of astronomy, there were successes in fluid dynamics, elasticity, the theory of continuous media; and towards the end of the 1700's the monumental works of Laplace and Lagrange on celestial and analytical mechanics. Then the phenomena of electrostatics and magnetostatics also fell into the same pattern. Against a fixed space-time background, all processes were describable in a causal and deterministic way. All this advance was possible to a great extent by separating natural science from preconceived notions and, so to say, allowing the phenomena to speak for themselves. As Max Born characterized Galileo and Newton: "The distinctive quality of these great thinkers was their ability to free themselves from the metaphysical traditions of their time and to express the results of observations and experiments in a new mathematical language regardless of any philosophical preconceptions".

Nevertheless the great philosopher Immanuel Kant made a deep attempt to explain these successes of Galilean-Newtonian principles. He combined the rationalist and the empiricist ways of thinking to arrive at a synthesis, a new point of view towards the nature of human knowledge. Rationalism is the view that, in Plato's words,

"…. Knowledge of nature does not require observation and is attainable through reason alone",

while empiricism holds that the laws of nature can be found only through experience. In Kant's approach there is a subtle combination of the two: there are both internal and external components to the way we understand Nature through science. These are called respectively the `a priori' and the `a posteriori' elements of thought. `A priori' means `in advance of experience', `a posteriori' means `as a result of experience'. The a priori in turn consists of two parts: the analytic, which are statements of pure logic or definitions; and the synthetic, which have nontrivial content and are assertions about properties of the actual world. Kant's idea was that the synthetic a priori principles exist in our minds even before we have any experience of the world, they provide a framework within which alone experience can be handled. Here are some examples: the concepts of separate and absolute space and time in the sense of Newton; Euclidean geometry of space; ideas of causality and the permanence of matter; and in later forms, also Newton's 3rd Law of Motion and the Law of Conservation of Matter.

Kant thus made some of the important elements of Galilean-Newtonian science into inevitable features of the world. They became preconditions for science, not results of experience, hence their automatic and necessary validity.

During the succeeding decades and centuries, physics moved into new realms where some of the Galilean-Newtonian ideas had to be modified. These changes came about successively through the development in the 1800's of Faraday-Maxwell electrodynamics, the discovery of non-Euclidean geometry within mathematics, and then the developments of relativity and quantum mechanics. In contrast to the action-at-a-distance concept which was accepted in the 18th century, the concept of the field and action by contact came to centre stage. This happened first for electromagnetism in the 19th century, and later for gravitation in the 20th. The separate absoluteness of space and of time has been replaced by a unified space-time, with a new meaning for distant simultaneity. In the microscopic domain there is a single conservation law subsuming the earlier separate laws for mass and for energy. Geometry has become a dynamical entity within physics, and gravitation is described in a non-Euclidean framework. From the strict determinism and causality of classical physics, we have moved to an irreducible probabilistic element, a statistical form of causality in quantum mechanics. So in an understandable way explorations into new domains of nature have shown the limitations of the earlier framework and of the Kantian picture.

Nevertheless, the profound combination of rationalism and empiricism, the a priori and the a posteriori, in the Kantian approach remains fascinating. And one is led to wonder: how could it happen that the synthetic a priori principles, assumed to be present in our minds before we meet the world, fit so much of later experience so well? If not from experience, then where do they come from?

Lorenz, Delbruck and the World of Middle Dimensions

A very interesting, in fact captivating, explanation came in the 1940's through the work of Konrad Lorenz based on the ideas of Darwinian evolution. For a physicist this is sure to be fascinating, and I will describe it briefly in a moment. However, maintaining the chronological sequence, let me first present the views expressed by the mathematician David Hilbert, and then by the physicist Carl von Weiszacker, on these questions. These were in the 1930's, about a decade before Lorenz's work. At his retirement in 1930 Hilbert had this to say:

"I…… believe that mathematical knowledge depends ultimately on some kind of such intuitive insights….. Thus the most general basic thought of Kant's theory of knowledge retains its importance… But the line between that which we possess a priori and that for which experience is necessary must be drawn differently by us than by Kant…. Kant's a priori theory contains anthropomorphic dross from which it must be freed. After we remove that, only that a priori will remain which also is the foundation of pure mathematical knowledge".

This was a mathematician's perspective. In the case of physics, here is an interesting episode again from around 1930. The philosopher Grete Hermann visited Heisenberg and his colleagues to discuss the role of Kantian ideas in the new situation created by the discovery of quantum mechanics. Her argument was that according to Kant, the law of causality is a synthetic a priori, it is a precondition for scientific work; in today's language it is not negotiable. In that case how can quantum mechanics deny strict causality and yet be a part of science? Here is Weiszacker's summing up after intense discussions between the philosopher and the physicists:

"……Kant gave a correct account of the state of scientific knowledge in his time …. I believe that Kant's analysis of human understanding represents true knowledge, not some vague expression of opinion, and that it will apply whenever thinking beings enter into the kind of contact with their environment to which we refer as \`experience'….. We should nevertheless remember that the very structure of human thought changes in the course of historical development. Science progresses not only because it helps to explain newly discovered facts, but also because it teaches us over and over again what the word \`understanding' may mean".

I will return later particularly to the last part of this statement on the meaning of understanding Nature. Since this year is full of Einstein, you may wonder what he had to say on Kant. Unfortunately he is rather non-committal, as he said in 1922:

"Arbitrary concepts are necessary in order to construct science; as to whether these concepts are given a priori or are arbitrary conventions, I can say nothing".

However, on another occasion at about the same time he was quite categorical:

"I am convinced that the philosophers have had a harmful effect upon the progress of scientific thinking in removing certain fundamental concepts from the domain of empiricism, where they are under our control, to the intangible heights of the a priori.

Now to Lorenz's analysis from the 1940's and its later eloquent presentation by Max Delbruck in the 1970's: According to Darwinian ideas, as a species develops over many generations and immense periods of time, new abilities continually arise essentially at random. Of these, those beneficial to dealing with the external world and surviving in it are retained and passed on to succeeding generations, while the others are weeded out or discarded. Here we appreciate that this very slow process of evolution by natural selection takes place through interaction with a narrow range of natural phenomena, a limited range of scales of length, time and energy. These collectively define what is called the `World of Middle Dimensions' – it is in contact with this limited part of Nature that life and the abilities of species evolve. As we would expect, through this slow process of `phylogenetic evolution', living organisms retain and refine just those capacities that are `tuned to' the most important features of this part of the world, because only this is relevant to biological survival. Thus each species goes through a slow learning process involving countless generations. Ultimately our intuitive concepts of space, time, geometry, causality, nature and permanence of matter, all arise from the experience of the species with a limited part of nature.

This phylogenetic development over millions of years is now to be contrasted with `ontogenetic development' – what happens to an individual organism between birth and death, a much shorter span of time. Each individual comes into the world so to say with all these evolved capabilities given ready made at birth. What the species has learnt slowly through experience of the World of Middle Dimensions over millennia seems given to the individual as a set of finely tuned abilities in advance of experience. No wonder they are so well adapted to dealing with this limited part of Nature. But in ontogeny too there is a process of learning. The phylogenetic inheritance of each individual is the capacity, not the content, for knowledge adapted to the World of Middle Dimensions. The actual acquisition of such knowledge is largely completed during infancy and early childhood. Let me at this point quote from Delbruck:

"Lorenz pointed out that the empiricist argument that knowledge about the world can enter the mind only through experience is valid if we consider only the ontogenetic development of man…. But once we also take into account the phylogenetic development of the human brain through evolutionary history, it becomes clear that persons can know something of the world innately, prior to and independent of their own experience….. These ideas are indeed a priori for the individual, but they did not fall from heaven; they are matters of evolutionary adaptation, designed for survival in the real world…. What is a priori for individuals is a posteriori for the species…. Thus we see the world through multiple pairs of glasses: some of them are inherited as part of our physiological apparatus, others acquired from direct experiences as we proceed through life".

There are thus two forms or sources of knowledge from experience – of the species, and of the individual – so each is a posteriori. But species experience effectively becomes a priori from the individual's view point.

It is interesting that the philosopher of science Hans Reichenbach had made the following categorical statement in 1944 in a discussion of the philosophic foundations of quantum mechanics:

"We cannot admit that there is any synthetic a priori principle, ie., a principle which is not logically empty and which physical theory is bound to satisfy".

While this is undoubtedly true, we now see that such synthetic a priori can subtly reenter the scene in the manner outlined by Lorenz and Delbruck. The origins and roles of the a priori and the a posteriori are placed in perspective by the idea of Darwinian evolution guided by natural selection, in a way not available in Kant's time, but we can see better the depth of his thinking. These are relative terms intertwined with phylogenetic and ontogenetic development. We have this immense saga of species evolution and learning built up out of so many individual organisms, their births and learning experiences and deaths, so many links in a vast chain of life, so much like a play within a play!

Let me return briefly to Einstein's remark of 1922. We now see that the capacity of the human mind to create new concepts is a result of evolution guided by natural selection, but it has gone far beyond immediate biological need. What is however amazing is that this capacity seems essential to discover the way Nature works. In that sense it is not wasted. Our desire to understand Nature needs this capacity for its fulfillment. Thus ultimately Einstein's somewhat noncommittal view about Kant has this link to the Lorenz-Delbruck analysis. The situation is beautifully captured in Julian Schwinger's words:

"It is remarkable how Nature aids mankind's groping towards an understanding of the universe. As we raise the level of our scientific skills and sharpen our artificial senses, fascinating new phenomena continue to appear, testing and challenging our growing comprehension of Nature's grand design".

The meaning of understanding Nature

With this background we can see why when we explore Nature in the microscopic and macroscopic domains far from our own scale, we find strange features clashing so strongly with our intuition. But then, how could we expect Nature to appear the same at all scales of length, mass and time? It becomes extremely difficult, especially in the quantum domain, to picture what is going on – because our abilities to make mental pictures were fashioned for a very different domain! So in these extreme reaches of Nature we have to rely increasingly on mathematical structures as our principal guides.

It is in this context that I go back to von Weiszacker's remarks on the changing meaning of the phrase `understanding Nature'. We can see the truth of this in many instances. When Newton found an action-at-a-distance description of gravity, he privately expressed difficulty in accepting it, but it worked. Then as a result of a century of successes it became the universal paradigm, readily extended to electric and magnetic forces. But at the next stage the field concept came in, and with it a return to notions of continuity and action by contact, only to be challenged later by the photon picture of light. The ether was presumed to be the carrier of electromagnetic waves for a long time, only to be given up after relativity. In quantum mechanics the subtle notions of states and physical quantities are far removed from our intuitive Middle World ideas, it is impossible to make any reliable mental pictures at all. Each success in mathematical description has been at the cost of concrete visualization of the kind one had become accustomed to. Step by step, questions earlier considered meaningful and answerable have turned into grammatically admissible but physically meaningless sentences. No wonder that Heisenberg admitted:

"Almost every progress in science has been paid for by a sacrifice, for almost every new intellectual achievement previous positions and conceptions had to be given up. Thus, in a way, the increase of knowledge and insight diminishes continually the scientist's claim on `understanding' Nature".

<u>Our place in the universe</u>

May be now you see why my title has the phrase `the Human Predicament'. Here we are, the results of biological evolution occupying an incredibly tiny niche in an immense universe, with elementary particles at one end and clusters of galaxies at the other, a range of about forty four orders of magnitude. Even within the four billion year old saga of life, we have been around for an incredibly short period of time – the hominid line is only about five million years old, and within that homo sapiens is a mere two hundred thousand years old. These may seem like long stretches of time in terms of one individual life span, but they are no more than like the twinkling of an eye in the billion year scale of life. And as far as we can tell, even our own appearance on the scene seems to have been a result of chance, not of necessity. We inherit the abilities as well as the limitations fashioned by phylogenetic evolution, and then seek to understand something far grander than ourselves in every sense. And yet we seem – at least to ourselves – to be succeeding surprisingly well.

This way of viewing ourselves in relation to Nature shows us how lonely we are as a species, how small a part of an immensity outside. Judged against the vastness of Nature, it is difficult to believe that we are central to it.

In spite of this realization, we may try to find a basis for moral and ethical principles – so important to govern our collective existence – in our scientific understanding of the universe. This is a swing from an external to an internal view of the situation, of our predicament. But here we find no solace. In Erwin Schrodinger's eloquent words:

"…..the scientific world view contains of itself no ethical values, no aesthetical values, not a word about our ultimate scope or destination, and no God…"

Einstein was even more categorical:

"…..every attempt to reduce ethics to scientific formulae must fail".

At this point we become aware of an amazing parallel between the profound loneliness of humankind as a component of the universe, and the sense of loneliness surrounding each individual human being, which is equally profound. There are deep uncrossable limits to communication between individuals. We believe that we all `see' the same colours, `hear' the same sounds, and think similar thoughts; but never can we ever know that this is so. To put across this point as forcefully as possible I turn to the writings of others because they say so much better what I too feel. In C.P. Snow's essay on `The Two Cultures' there is this passage:

"Most of the scientists I have known well have felt - just as deeply as the nonscientists I have known well – that the individual condition of each of us is tragic. Each of us is alone: sometimes we escape from solitariness, through love or affection or perhaps creative moments, but these triumphs of life are pools of light we make for ourselves while the edge of the road is black: each of us dies alone…. Each of us is solitary"

Against this background he nevertheless sees value in trying to do something for the collective good. This solitariness is even more poignantly expressed by Schrodinger in his book `My View of the World'. Here are several passages that do so:

"….. each person's sense world is strictly private and not directly accessible to anyone else….."

"……that inexorable, absolute division between spheres of consciousness…."

"….breaking through that privacy and separateness on which we have touched so often…..that is impossible".

"…..the inexorable separateness of spheres of consciousness, and their total and impenetrable exclusion of each other….."

And yet, as social beings created by evolution, we crave contact and companionship. Einstein put it this way:

"Man is, at one and the same time, a solitary and a social being".

In spite of this loneliness, there is the possibility of some degree of communication between individuals, and a surprising degree of apparent commonality in the pictures of the world they separately create.

This whole situation seems so paradoxical – so much apparently shared collective knowledge, and yet an unbridgeable gulf, a separateness between individuals. I am inclined to conclude that, though science itself as an intellectual effort is unable to lead to feelings of a moral or ethical nature, these can arise from a feeling of compassion that each of us should have towards every other, since we are each in the same predicament. That word again! One of Einstein's frequently quoted lines is:

"Science without religion is lame, religion without science is blind".

However I feel a sense of starkness in these words. Expand `science' to the more inclusive word `knowledge', and replace `religion' by the more gentle word `compassion'. You are then led to this statement from Victor Weisskopf which is more deeply meaningful, humane and wise:

"Human existence is based upon two pillars: compassion and knowledge. Compassion without knowledge is ineffective; knowledge without compassion is inhuman".

That is our predicament. Both components are essential to our functioning, and possibly the scientist has the greater chance of grasping this truth and therefore the greater responsibility.

TIFR ALUMNI ASSOCIATION BEST THESIS AWARDS 2004-05

We congratulate the following alumni for being selected for TAA awards and honorable mention in the respective fields.

Physical Sciences:

TAA - Geeta Udgaonkar Award

Dr. Arvinder Singh Sandhu, *Department of Nuclear Atomic Physics.*

Honorable mention to Dr. Biswajit Karmarkar, *Department of Condensed Matter Physics & MS*

Mathematics:

TAA - Harish Chandra Memorial Award

Dr. A. Bhattacharya, *School of Mathematics*

Biological and Chemical Sciences:

TAA - Zita Lobo Memorial Award

Dr. Vasundhara Navadgi, *Department of Biological Sciences.*

Technology & Computer Sciences:

TAA - Sasken Award

Dr. Rahul Jain, School of Technology & Computer Sciences.

All the four best Ph.D. thesis awards at TIFR are co-sponsored by *Sasken Communication Technologies Limited, Bangalore.*

Recent HONOURS to ALUMNI

Young Scientist Award-2006 – medal from Indian National Science Academy (INSA) - *Anandya Ghosh Roy.*

Rajib Goyal Young Scientist Prize-2005– *VPS Awana*

R.C. Mehrotra Life Time Achievement Award – *Girjesh Govil.*

Director of the Space Science and Technology Education in Asia and the Pacific – *George Joseph*

Elected as Vice President, Commission 47 on Cosmology of International Astronomical Union: *T. Padmanabhan*

Third Prize Gravity Essay Contest 2006- *T. Padmanabhan*

Trieste Science Prize of the Academy of Sciences for the Developing World – *C.S. Seshadri*

Election to Academies

K. P. Singh: *Fellow of the National Academy of Sciences, India.*

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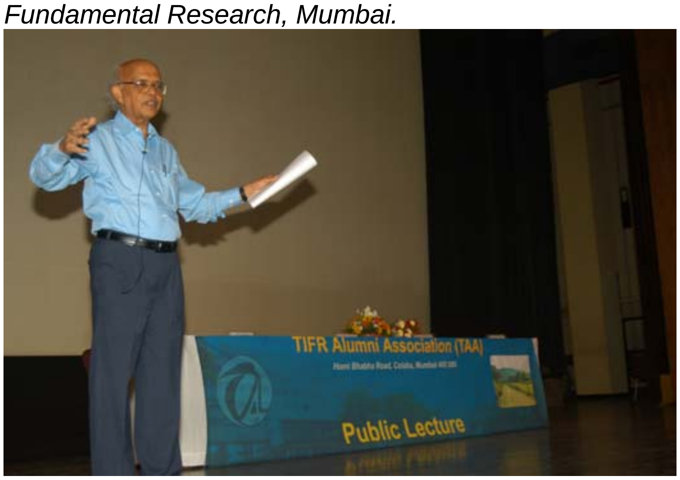
RADIO WAVES AND THE UNIVERSE

Govind Swarup
NCRA-TIFR, Pune-411 007

Public Lecture on February 28th 2006, National Science Day, at Homi Bhabha Auditorium, Tata Institute of Fundamental Research, Mumbai.



In my talk today, I plan to give an overview of the fascinating world of radio astronomy and our work in this field at TIFR during the last 40 years.

Man has always wondered about the origin and evolution of the Universe. Using powerful optical telescopes, astronomers have discovered that there are billions of galaxies in the Universe, each having billions of stars. Our Universe is indeed very vast. Stars shine because they are hot. Stars also give rise to radio waves but they are extremely weak. Radio waves are electromagnetic in nature, as are light waves or X-rays. Powerful radio waves arise when electrons move coherently, OR when electrons spiral in the presence of magnetic fields with relativistic velocities.

During 1950's, radio astronomers made a great discovery that one in a million galaxy is a powerful source of radio waves. Many strong radio sources were also discovered in our Galaxy. For many years the nature of these celestial radio sources was a great mystery. It is now well established that radio waves arise from celestial sources when catastrophic events occur in the Universe, such as collapse of a star. Hundreds of remnants of collapsed stars, called supernova remnants and pulsating radio sources (pulsars) have been discovered in our Galaxy by radio astronomers over the last few decades.

The most powerful radio sources in the Universe are radio galaxies and quasars. These are extremely powerful and many thousand time more copious than visible galaxies. It is believed that at the centre of a powerful radio galaxy or a quasar lies a massive object, most likely a black hole, which has a mass of more than million times that of our Sun. This central object gives rise to jets of relativistic electrons, which propagate outwards and result in a radio galaxy or a compact quasar. Because of their large power, radio galaxies and quasars are seen up to very large distances and allow us to study the large scale structure of the Universe.

I returned to India in 1963 from USA to join the Tata Institute of Fundamental Research as a result of immediate response and a very encouraging support given by Dr. Homi Bhabha in response to a letter sent by T. Krishnan, M.R. Kundu,T. K. Menon and me to Dr. Bhabha, UGC, CSIR and other agencies. As a first project I set up the Kalyan Radio Telescope along with V. K. Kapahi, J. D. Isloor and R. P. Sinha during 1963 - 65.

At that time there was a great controversy between the Big Bang theory and the Steady State theory for the origin and evolution of the Universe. During 1950's, observations by Martin Ryle and co-workers at Cambridge in U.K. had shown that there was an excess of weak radio sources in the radio catalogue made by them in comparison to the predictions of the Euclidean Universe. Assuming that the weaker sources were very far away, they concluded a support for the Big Bang Model but Fred Hoyle argued that how does one know that the weaker radio sources are far away!

According to the Big Bang Model the Universe was much smaller in the distant past, originating about 13 billion years ago, and has been expanding ever since. This model predicts that density of radio sources was much higher when the Universe was smaller. But, there were no available instruments in the world in 1960s to measure detailed properties of the weak and distant radio sources, such as their angular size.

Recognizing advantage of India's location near the geographic equator, I proposed in June 1963 the construction of a unique Radio Telescope in 1963, which was set up at Ooty by 1970. The Ooty radio telescope consists of a 530 m long and 30 m wide parabolic cylindrical antenna which is placed on a hill so that its axis of rotation becomes parallel to that of the earth. The telescope was designed to track moon for ten hours per day. The positions and angular size of over 1000 weak radio sources were measured for the first time, as they got occulted or eclipsed due to the motion of the Moon in the sky. Studies of the Ooty data by Kapahi, Subrahmanya, Kulkarni and myself provided a strong support to the Big Bang Model. We tracked

Moon for over 10 years and used to joke that we were the only professional lunatics in the world! The Ooty telescope is now being used for studying pulsating radio sources and solar wind. Successful completion of the Ooty Radio Telescope during 1960s depended not only due to a close team work of the members of the radio astronomy group but also by the administration and workshop staff at TIFR in Bombay.

There are many great puzzles concerning the Universe today. One of the important question is as to when did the galaxies form. According to the Big Bang model, hydrogen is the building block of the Universe, and it got formed when the Universe was very hot. These hydrogen clouds cooled and gravitationally collapsed subsequently to form stars and galaxies.

In 1984 we proposed the construction of the Giant Metrewave Radio Telescope (GMRT). One of its major objectives was to search for the cold hydrogen clouds that must have existed in the early Universe. India's relatively low radio noise compared to that in the developed countries gives us an advantage for exploring the radio Universe at metrewaves.

GMRT consists of 30 nos. of fully steer-able parabolic dishes, each of 45-m diameter. A novel and economical design has been chosen for these antennas. Their reflecting surface is made of Stretched Mesh Attached to Rope Trusses, which we have nicknamed SMART design. The welded wire mesh consists of fine (0.55 mm) stainless steel wires which were chosen in order to cut down the wind loading. The wire mesh was specially developed for GMRT by a firm in Mumbai. The firm has exported similar mesh subsequently for the Arecibo Telescope in USA and also for the Mauritius Radio Telescope.

The antennas are located in an array of about 25 km in extent. With the rotation of the earth, the relative orientation of these antennas changes with respect to the celestial coordinates and thus a 25 km aperture gets synthesized. Over the last 25 years, radio astronomers have developed many ingenious image processing techniques, which allow self-calibration of any instrumental and atmospheric errors. Thus, GMRT operates as if it is a perfect 25 km diameter parabolic dish antenna !

State of art RF and digital electronics have been built for GMRT by NCRA engineers, making it a very powerful instrument. GMRT is located about 70 km north of Pune. This site was selected so as to be far away from various radio transmitters in Pune and its vicinity.

GMRT is designed to operate in the frequency range of about 38 MHz to 1430 MHz. It is the world's largest radio telescope operating in this frequency range.

GMRT is a very versatile instrument. It allows studies of a wide variety of celestial objects, ranging from our Sun to the most distant radio galaxies in the Universe. GMRT has been operational for the last five years and. Its great success is solely due to the very close team work of all the members of NCRA and also due to the leadership provided by the present group of scientists and engineers at NCRA.

Amongst many outstanding results obtained by NCRA scientists, only a few are cited here: recent discovery of a pulsar in a Crab like supernova remnant with a deduced age of about 4000 years, another in a Globular cluster with a very high ellipticity, discovery of 3 more pulsars in distant parts of our Galaxy, HI and OH observations giving constraints on fine structure constant, studies of HI in our Galaxy, nearby galaxies, particularly dwarf galaxies with much higher sensitivity than available before, discovery of several supernova remnants, search for micro-quasars in our Galaxy particularly those associated with gamma ray sources, studies of the Galactic Centre, nearby galaxies, giant radio galaxies, X-shaped radio sources, etc.

Over the last few decades the young science of radio astronomy has revolutionized our understanding of the Universe. Many great discoveries have been made. GMRT provides a great opportunity to students and scientists in India to work at the frontiers of science and engineering. It is also being used by more than 200 scientists from about 20 countries in the world. I have no doubt that the era of discoveries through the radio window will continue for decades to come. There are many challenges ahead, including searches for the probable Extra Terrestrial Intelligence (SETI).

SUPPLEMENTARY LIST OF REGISTERED MEMBERS OF TIFR ALUMNI ASSOCIATION

(This list consists of names of new members and those that did not appear in previous editions of the Newsletters available as PDF files on the TAA website.)

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EDUCATION, KNOWLEDGE AND INDIA'S SOVEREIGNTY

by

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Mahatma Jotirao Phule, in his Memorandum submitted to the Indian Education Commission (1882), told the British rulers that while most of the government revenues came from the productive labour of the peasantry, the majority of the benefits of the state-funded education flowed to the upper classes and upper castes. Mahatma Phule's observations would be equally applicable to the education policy being followed today.

Almost 125 years later, the Draft Right to Education Bill 2005 was withheld by the Prime Minister's office since August 2005 for more than ten months, spuriously claiming lack of resources. This Draft Bill was already a highly diluted and distorted version of the government's Constitutional obligation under Article 21A that was introduced by the 86th Constitutional Amendment (2002). The Central Government has abdicated even this modicum of its obligation and has instead sent an entirely revised version to the state governments in June 2006 that essentially amounts to a total withdrawal of the Right to Education as given by the 86th Amendment four years ago. In line with this thinking, the Eleventh Plan (2007-2012) Approach Paper does not even recognise the historical event of the 86th Amendment. Its proposal to introduce the voucher system is designed to demolish the government school system altogether and also to fund privatisation of school education from the backdoor.

As of now, no political party is known to have taken an official stand against this violation of the Constitution and denial of the Fundamental Right to almost 20 crore children in the 6-14 year age group – i.e. one-fifth of the nation's population. The corporate houses and their business federations are also silent on denial of access to knowledge to almost two-thirds of India's people – i.e. SCs, STs, most backward among OBCs, minorities and the disabled, the girls in each of these sections being the worst victims of this historical discrimination and injustice. More than 80-85% % of the SC girls and 90% of the ST girls are unable to complete even High School education. Yet, the India Inc. unabashedly talks of making India the third largest "Knowledge Economy" and a superpower by 2020!

The 1986 education policy had resolved to raise investment in education such that it will reach at least 6% of GDP by the year 2000. This unfulfilled resolve was incorporated in the UPA's Common Minimum Programme in May 2004. Yet, as percentage of GDP, India spent less on education in 2005-06 (less than 3.5% of GDP) than what it spent in 1985-86 when the policy was passed by the Parliament. This is despite the fact that the Government has levied 2% Education Cess and taken a substantial loan from international agencies for Sarva Shiksha Abhiyan. Clearly, the political will to mobilize public resources for education today is at a lower level than what it was 20 years ago!

Following the elevation of elementary education to the status of a Fundamental Right, the government is under obligation to ensure that no expenditure that is not covered under the Fundamental Rights is given priority over a cause like elementary education flowing out of both Articles 21 (Right to Life) and the associated Article 21A (Right to Education). Yet, the Government is reportedly going ahead with more than Rs. 80,000 crores of new investments for staging the Commonwealth Games in 2010 – a matter not covered under the Fundamental Rights. A recent report of the Reserve Bank of India on Non-Performing Assets reveals that debts worth tens of thousands of crores owed by the Indian corporate houses were written off while this did not constitute a Fundamental Right of the India Inc. Evidently, in the age of globalization, the Constitution does not matter to the policy makers in prioritizing the Indian economy.

The rhetoric of lack of resources was given a new turn with the announcement of the New Economic Policy in 1991. The new element was IMF-World Bank's Structural Adjustment Programme imposed on the Indian economy as a pre-condition to receiving fresh international loans/grants. This meant that the Indian government was obliged to steadily reduce its expenditure on the social sector, particularly health and education. This was a rather enigmatic pre-condition in a country where the vast majority of the people did not have access to quality health or education. In education, it made even less sense as it was imposed by those who were advocating a move towards the so-called "Knowledge Economy". One can't, therefore, avoid asking the question: what was the hidden agenda? An analysis of the declaration issued by the World Bank-UN sponsored "World Conference on Education for All" (1990) reveals that the central thesis was three-fold. First, the State must abdicate its Constitutional obligation towards the education of the poor. Second, the people neither have a human right as enshrined in the UN Charter nor a Fundamental Right to receiving free education of *equitable* quality as provided through the 86th Amendment in India's Constitution. Third, education is a commodity that can be marketed in the global market. It follows, therefore, that the education system - from the pre-school stage to higher education - must be, as rapidly as possible, privatized and commercialised. This central thesis has originated from the highest echelons of the global market economy and the Indian Parliament, along with India Inc., has unfortunately acquiesced, presumably in larger "national interest". Prof. Noam Chomsky, the redoubtable US scholar-cum-activist, would not have found a more shameful example of his proposition of "manufacturing of consent"!

In smaller countries, particularly in the ones lacking a strong base of government-funded schools, the above neo-liberal agenda would not be hard to implement. However, in a vast country like India, having a rich history of government's engagement in education, the neo-liberal agenda called for a special strategy. The Indian situation was marked by glaring contradictions. On the one hand, a whole generation of academia, writers, scientists, doctors and engineers, civil servants, lawyers and public figures until the 1990s had been, by and large, nurtured in the government-supported education system. In 1991, the massive school network comprised more than 8 lakh schools (the figure has grown to one million today), 94% of which were either government/local body or private but government-aided schools. Less than 6% were private unaided schools. The higher education system then comprised about 5,000 colleges, 1,000 professional institutions and 200 universities. It is no body's case, on the other hand, that the system was adequate – either in quantity or in quality. Half of the nation's children (and two-thirds of the girls) were essentially out of school – unable to complete even eight years of elementary education. The Constitutional goal of achieving universal elementary education by 1960 eluded the policy makers, as it continues to do even today. A conservative estimate showed that the number of primary schools needed to be increased by almost two-fold while the number of upper primary and secondary schools needed to multiply several fold. We needed *at least* twice as many qualified and well-trained school teachers as we had in 1991 (this number was about 40 lakhs).

By and large, our schools were 'efficient' cramming centres. Attributes such as curiosity, exploration, reasoning, aesthetics and creativity faced attrition. The inherent potential capacity of the children in all three critical dimensions – cognitive, emotional and value-based and skill-oriented – was more likely to be suppressed, than harnessed optimally. The higher education system, the handful of elite institutions notwithstanding, was unable to meet the nation's quest for higher knowledge. The persistent underinvestment in education since independence had by this time steadily built up into a huge cumulative gap of resources, running into lakhs of crores of rupees.

What the country needed in 1991 – five years after the 1986 policy – was a firm resolve to first rapidly fill up the cumulative gap resulting from underinvestment and then maintain the elusive investment level of 6% of GDP in the coming decades. Nothing short of a radical departure was long awaited in order **to energise and restructure the entire education system along with its curriculum**. Yet, what the global market forces persuaded the Indian State to do in the 1990s was precisely the opposite of what was directed by the Constitution and resolved by the 1986 policy. The undeclared but operative strategy was to "let the vast government education system (from schools to universities) starve of funds and, consequently, deteriorate in quality." As the quality would decline, resulting in low learning levels, the parents, even the poor among them, would begin to withdraw their children from the system. A sense of desperation and exclusion from the socio-economic and political space in the country would prevail.

When the children "walk-out" of the schools in protest against poor quality and irrelevance (no child ever drops out, the official claims notwithstanding!), two possibilities would emerge. First, low fee-charging unaided private schools (recognized or unrecognized) would mushroom to meet the new demand. Second, the government would have an *alibi* for closing down its schools as their low enrolment would have made them unviable. The school campuses would then be converted into commercial ventures or police stations, as it has been happening all over the country. The latter and a well-equipped police force will increasingly become the State's priority in order to control the young people turning into lumpen elements (or terrorists/drug traffickers) as they were excluded from these very schools only a few years earlier. More importantly, the opportunity of socialisation necessary for becoming part of even the bourgeois vision of the nation through schools and colleges was effectively denied to them. Yet, this is what would be unabashedly termed "rationalization" of the school system in the official reports. The 1990s and the beginning of the 21st century stand witness to this phenomenon. The neo-liberal agenda was operating as per its original design!

The public expectations from the government system posed another challenge to the global market forces. Arguably, a general unrest in the country might be expected if the above strategy became too apparent. The World Bank-sponsored District Primary Education Programme (DPEP), therefore, took a cue from the 1986 policy's non-formal stream for the poor. It started promoting low quality parallel streams, rather than provide more regular schools. From 1993-94 onwards, the DPEP pushed and eulogized all kinds of parallel streams such as alternative schools, education guarantee centres, multi-grade teaching and bridge courses – anything but a regular school! The cadre of teachers was rapidly replaced by *para*-teachers i.e. under-qualified, untrained and under-paid young persons appointed on short-term contract. A new sociological principle emerged: a separate layer of educational facility according to the social and economic status of the child. A **Common School System functioning through Neighbourhood Schools** would have enabled children of different class, caste, religious and language backgrounds to study and socialise together, thereby promoting social cohesion and understanding of India's rich diversity and composite culture. Instead, the emerging system, as supported by the neo-liberal agenda, was designed to isolate and alienate children belonging to different sections of society. The Indian Constitution was in tatters.

All these dilutions were adopted during the 1990s in World Bank's DPEP in more than half of India's districts spread over 18 states. None of these policy measures were formally approved by the Parliament, though they were violating the Constitution's principle of equality and social justice. The much-hyped Sarva Shisksha Abhiyan packaged all these measures into one scheme and sought legitimacy through the Tenth Plan. The Parliament was no more the supreme policy-making body. Directions were coming from the World Bank and such other agencies representing the global market.

The Ambani-Birla Report (2000), submitted to the Prime Minister's office, was yet another example of how the market forces began to erode India's sovereignty and the democratic process of the Parliament. It introduced several new formulations in the policy discourse in India **to convert education at all levels into a marketable commodity.** Once this is accepted in principle, **a paradigm shift follows by implication.** Although the Ambani-Birla Report was never approved by the Parliament, most of its recommendations are now being implemented in rapid succession.

It is time that the paradigm shift in the framework that determines the character of knowledge is recognised. The epistemic (i.e. knowledge-related) implications that flow out of this paradigm shift dominate the policy discourse and decision-making at all levels – legislature, executive and the judiciary. The global market forces, supported by the India Inc., have discovered new avenues, spaces and ways and means in this market-oriented anti-people framework to powerfully intervene and to further dilute and distort policies. The Indian academia and activists, by and large, stand co-opted in this process.

The goals of the market-oriented education policy are in direct conflict with the social vision of the Constitution. The assault by the market forces on the character of knowledge is rapidly marginalizing the educational goal of preparing citizenry for a democratic, egalitarian, secular and enlightened society. The Eleventh Plan's Approach Paper on secondary education, in the context of extending it to the under-privileged sections of society, states that the focus of secondary education shall be to prepare skilled workforce for the global market. In contrast, the elite would be given access to the highest forms of knowledge on a priority basis and thus enabled to shift to the advanced countries and serve the global "Knowledge Economy". The twist given by the government to the recent reservation debate is yet another evidence of the dominance of the market agenda. The market assault is not merely in terms of denying education of equitable quality but also in terms of the social and pedagogical character of knowledge itself. This is to be viewed as an epistemological assault on the generation, distribution and transaction of knowledge. The challenge is now being increasingly deciphered by the people's movements. Education is certain to be accepted as the fourth critical resource, apart from *jal-jangal-jameen*, for the survival of the struggling masses. Herein lies the emerging agenda for the people's movement to retrieve India's sovereignty!

Remembering Prof. L.K. Pandit

We are very sad to announce the passing away of Prof. LK Pandit ji. A biographical sketch has been presented by Probir Roy published in the Current Science called "Lalit Kumar Pandit (1932-2006)"

http://www.ias.ac.in/currsci/aug102006/379.pdf

Remembering Prof. C.V.K. Baba

Prof. C.V.K. Baba, or Babaji as he was known to us, is no more. He was undergoing treatment for lung cancer for the last few months. However, the sudden

deterioration of his health causing his death on the night of the 5th December, 2006, came as a shock to all of us. He leaves behind his wife Sukanya, daughter Prasanna and son Srinath.

Babaji joined the 1st batch of the Atomic Energy Training School and later joined Prof. Bhattacherjee's group at TIFR. His main area of research was nuclear spectroscopy using radioactive sources involving measurements of nuclear lifetimes, magnetic moments, beta-gamma angular correlations and conversion electrons. Almost all the equipment was home built including many electronic modules which were wired by CVK himself. Around 1962 he visited Niels Bohr Institute where he collaborated with P.G. Hansen. He completed his Ph.D. in 1963. He received the prestigious Alexander von Humboldt fellowship to work at the Technical University of Munich (1971-73). There he proposed and carried out a beautiful measurement of the difference of two g-factors in ^{210}Po using the perturbed angular correlation technique. After his return, he decided to shift to BARC. This move helped start an accelerator based nuclear spectroscopy programme at Van de Graaff, BARC. In the later part of his stint at BARC, although only a few experiments could be done due to the aging of the accelerator, his enthusiasm remained undiminished. He just took up different problems such as the assignment of a radiative decay from an isomeric excited state in Li^-, search for particle bound polyneutrons in the fission of ^{236}U, search for a neutron-proton mean field radial difference using the beta decay of ^{209}Tl, search for the light axion in radiative neutron capture by protons at the 220 MW Tarapur reactor etc. He was open to ideas by other group members, the 17 keV neutrino search in the beta decay of ^{35}S being one such example. He was one of the pioneering members of the Pelletron accelerator project, which has been the backbone of nuclear physics research activities for the past 20 years. Around 1986 he shifted back to TIFR and started a program to study heavy ion reactions around the Coulomb barrier using the Pelletron accelerator. He was an active member of the TIFR − Pune University joint M.Sc. (Physics) programme. Many students from this programme, which lasted for three years, pursued nuclear physics at TIFR and elsewhere in the country. After his retirement in 1997, he was associated with the Nuclear Science Centre, New Delhi and gave lecture courses there as well as at several universities.

Babaji was a great teacher, excellent physicist and above all a great human being. He personified simplicity. Those who have interacted with him were touched by his passion for science. He inculcated among many of us an appreciation of good science. He was always enthusiastic about interacting with, and motivating, younger colleagues and students. His understanding of physics, clarity of thinking and experimental skill has inspired many a young researcher.

I was fortunate to have started my career with his group at Van de Graaff laboratory of Nuclear Physics Division, BARC. At the time of joining I was told by some colleagues that CVK was a very tough person to work with but that he was very active and good in his subject. I found him quite unlike what I had imagined him to be. Although he was very much my senior, I found his general attitude very friendly and straightforward, without any airs. One of the early experiments that I participated was on the intermediate structure in ^{72}Ge(p,γ). The broad structures in the excitation function correlated nicely with those seen in the ^{72}Ge(p,p′e) using the six-gap spectrometer. It was his idea that these structures could be states in an excited deformed second well, akin to those seen in fission isomers. At his instance we even looked, unsuccessfully as it turned out, for further corroborating evidence through γ-γ coincidence measurements. I remember animated discussions with CVK, Amit Roy and Betigeri. Even if we did not find what we were looking for, the experience of formulating a physics question and devising an experiment to try to get an answer was quite exciting.

CVK devised a simple technique to scan the excitation function by ramping the reference voltage of the analyzing magnet and hence the energy of the analysed beam from the Van de Graaff at Trombay. This trick reduced significantly the labour and systematic error in measuring an excitation function. Around that time, I also came to know of the "Baba magnets", horseshoe magnets used in vacuum discharge gauges at that time, put at appropriate places on the beam line to steer the beam onto the target. Such a magnet, on his suggestion, was also used recently to reduce the secondary electron background from the superconducting RF cavity while making time profile measurements of the LINAC beam.

Having him around on night shifts at Van de Graaff used to be very pleasant as also instructive. We used to plot spectra manually during the experiment, in keeping with his view that we should analyze as much data as possible during the experiment to ensure that we are on the right track. His cardinal rules were that you must understand what you are doing, always be alert during the run, and if you notice something wrong, stop data taking and rectify it. Discussions with Babaji were always illuminating. You could ask him any question without hesitation. He wrote down a quote from Bohr, in a SERC School on Nuclear Physics at BHU (1990) viz, "There are no stupid questions - only stupid answers". He would explain in simple, understandable terms and sometimes ask questions to know how much of the discussions were 'sticking'. We did several experiments together at VECC and at the Pelletrons at Mumbai and Delhi. Even during his last visit to Mumbai in Sept.2006, he discussed our experiments with his usual enthusiasm.

He was a strong supporter of the effort to build an underground laboratory for neutrino physics. In fact it was due to his early groundwork with colleagues at IMSc, Chennai that Pushep is the preferred site for INO. The choice of ICAL as the major detector there is also mainly due to him. Making a success of this project including the other planned experiments there, such as the neutrinoless double beta decay experiment (with the ^{124}Sn cryogenic bolometer) and a low energy ion accelerator for nuclear cross sections of astrophysical interest, would be a fitting tribute to his memory.

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Notices sent to a large number of email addresses have started bouncing. Please inform other alumni as well.

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