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Breakthrough, Vol.17, No.1, July 2014

Corridors of Cosmology and Prof. Jayant Narlikar

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1. Encounters

ONE CAN SAY that the 1930s was a period of scientific revolution in cosmology. The paradigm of static universe, which unknowingly influenced even Einstein, fell flat. Its fall was easy since the paradigm itself had no long history and there were not many people who worked on it. Even then, the route to the new big bang paradigm was not unchallenged. In those days, there were more than one paradigm competing with the big bang model, but this is hardly mentioned in today's textbooks. The reason for this is that, as Thomas Kuhn describes correctly, today's textbooks are written in the new paradigm. In this period of crisis, the paradigm of Friedman, Eddington, Lamaitre and Hubble has engaged in several pitched battles with the alternative paradigms. It was during this crisis that the big bang model could make and implement new weapons and thereby attain a professionalisation which helped it to reach the status of "normal science." For these reasons, the history of cosmology in this period is valuable for curious minds.

Even though most of the people who participated in these controversies were scientists, one can see that they all were very clear about the philosophical overtones of their positions. In those hair-splitting discussions of the 1930s on the philosophy and methodology of science, there were two main camps. In the opinion of one of these camps, formulation of theory involved two closely-linked steps. First, one begins from the empirical observations, i.e., from measurements, observations and experiments, whose results were evident to the human senses. This is classic empiricist epistemology. Observational results would then suggest which are the possible hypotheses, and these would then be examined through further empirical testing. When enough data concerning the hypothesis had been gathered, logical generalization could be carried out, thereby producing a theory. This is classic inductivist logic. Eddington, de Sitter, etc., attempted to build the big bang model along these lines—on the basis of Hubble's observations.

There was an alternative viewpoint to this, a leading figure of which was the famous British astronomer E. A. Milne. In this method of constructing science, one first proposes hypotheses and then by strict logical reasoning make predictions about observations. This is called hypothetico-deductivism. They considered that there are some principles, which the universe must obey. The acceptability of these hypotheses was on the basis of their axiomaticity or simplicity. According to this camp, science is all about testing the predictions of such hypotheses.

The standard big bang cosmology is the logical conclusion of the first approach. The

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second stream gave birth to the steady state cosmological model, which was popular in later years. The cosmological principle is the fundamental principle in big bang model and the principle says that the universe looks the same, everywhere (on a large scale) and in every direction. It was by modifying this principle to the ‘perfect cosmological principle’ that Herman Bondi, Thomas Gold and Fred Hoyle made the steady state model. This new principle tells that the universe looks the same, not only in every place and direction, but also at all times. One can deduce the steady state model from this principle.

One of the alternative models that appeared soon after Hubble’s discovery, and did compete with the big bang model, is the kinematic relativity by Milne. While the big bang model is based on general relativity, the Milne’s model was based on special relativity only. Milne was a critique of concepts such as curved space, etc., that appeared in general relativity. His philosophical position, which is often called positivism, did not allow him to endorse the ideas of expanding space, spacetime, etc. He imagined, in his model, that the celestial objects are moving out from the same point, with varying velocities. Even the force of gravity was not taken into account in this model. Milne considered gravity as a force, effective only at relatively small distances. He maintained that the picture we get by considering objects going out with different but constant velocities can be considered a realistic one. This kind of a cosmic scenario is sometimes called a coasting model. It was believed that subsequent observations did not support the model and hence people lost interest in it quite soon. But it enjoys interest as a pedagogical model, even today.

Historically, it was Milne who developed the arguments which led to the concept of a cosmic time, operationally defined with the help of clocks and light signals. He gave only such operational definitions even to concepts like space and time. It was Eddington who first came forward strongly against Milne’s views. In his opinion, the concepts of general relativity are not only useful, but also essential. In an article submitted to Nature, Eddington discarded Milne’s hypothetico-deductivism and perfect cosmological principle—even though many of Milne’s operational definitions are used in mainstream cosmology even today. About this, Wittaker later remarked that the situation that led to Milne’s break with a tradition including at least Einstein, de Sitter, Friedmann, Lemaitre, Weyl, Eddington, H.P. Robertson and others is to be regretted.

In 1949, Milne was selected as the Chairman of the Royal Astronomical Society, London. In his inaugural address, while mentioning the predictive power of theories, he repeated his position that those theories which are not philosophically satisfactory are not acceptable. However, since after Walker, there were not much research students working with him, the ideas of Milne were soon forgotten.

2. The Steady State Model

In 1948, Herman Bondi and Thomas Gold presented the steady state model on the basis of perfect cosmological principle. In Milne’s language, it was ‘philosophically more satisfactory’. While Bondi and Gold developed its geometry, the same year Fred Hoyle reached at this idea by introducing a new postulate on the matter/energy content in the universe.

Bondi was very well aware of the philosophical overtones of this model. He could appreciate that both schools, the empirical-inductivist school and the opposing hypothetico-deductivist school had their own merits and demerits. He also believed strongly that the theories belonging to the second category should necessarily be tested experimentally or observationally. In such affairs, Bondi took seriously the criterion of 'falsifiability' suggested by Karl Popper. This criterion says that every theory in science should be in principle falsifiable, and hence the scientist proposing a theory has to clearly state which observations or outcomes of which experiments will definitely show that his theory is false. Even though the application of the falsifiability criterion is difficult in sciences like cosmology where there are limitations for experiments or observations, the main attempt of Bondi and coworkers were to demonstrate that their own theory was in principle falsifiable, and hence is a proper candidate as a cosmological theory. Bondi has reiterated his indebtedness to Popper:

> 'I think the person from whom we had most help on the philosophical side was Popper. His analysis of science encouraged one to be imaginative, and encouraged one to go for something that was very rigid and therefore empirically disprovable.'

All cosmological models are based on physics. We can make a cosmological model on this basis only by assuming that the laws of physics are unchanging in time, just as they are valid at every position. Given this, it is logical to assume that the universe itself is in a steady state, looking the same everywhere and at all times. This is the 'perfect cosmological principle'. The proponents of the steady state theory asked how the universe can have a beginning and an end, when we assume that the laws of physics are unchanging[1]. Following Popper, they also argued that this principle is falsifiable and hence satisfies the essential requirements of a good scientific model. "Show me some fossils from an evolving universe, and I'll give up the steady state theory", Bondi once said.

It should be noted that the steady state model is quite different from Einstein's static universe, which neither expands nor contracts. In the steady state picture, the universe is really expanding. Then how can it be steady? The Hubble parameter is a measure of the expansion rate of the universe and in the big bang model, its value changes continuously. Also at $t = 0$, the time of big bang in this model, the value of Hubble parameter is infinity. But to make a steady state model, we have first to assume this value to be a constant. One can understand the basics of steady state model by following a few mathematical steps, starting from this. As can be done in several other models, even though space-time is curved, we can consider space as flat in this model too. But an important factor which makes this model steady is the structure of matter/energy assumed in it. As the universe expands, the distance between objects will certainly increase. When this happens, if new objects are created in the newly created space, the universe may look the same at all times, i.e., it may appear steady. Thus a characteristic feature of this model is that it has continuous creation of matter. Many scientists found this aspect unacceptable, again on philosophical grounds. Then there arises the question whether this kind of continuous creation is observed in nature. But calculations show that there need to be only the creation of one proton or one neutron in a volume of size 1 km^3 and hence none of the experiments or observations we can perform today will be able to detect this. However, one should make it clear at which place this creation takes place—

[1]On this issue the proposents of big bang theory say that the laws of physics "break down" at the big bang singularity.

whether it is at the centre of galaxies or in the vast empty spaces (voids) found between galaxies or in galaxy clusters? The famous cosmologist Steven Weinberg accuses that this model is silent on this issue. It is also not known how this process occurs and from where the energy required for this comes. If we do not want the violation of energy conditions, one should assume an unknown field—the creation field—for this purpose. It was Fred Hoyle who worked out the details of this field.

Among other things that can be put to observational tests in this context comes the rate of change of expansion rate itself, which is called the deceleration parameter. This too can be found using the help of observational data, just as one finds the Hubble parameter. Since the expansion rate decreases in the big bang model, the deceleration parameter, as it is defined, is positive. But in the steady state case, this ought to be negative. In fact, there is a clear-cut prediction in that model: that the deceleration parameter $= -1$, which means that the expansion of the universe must be accelerating. The observations till 1998 were generally supportive of the big bang model. But the newly discovered accelerated expansion of the universe supports the steady state model, at least in this aspect.

Strictly speaking, both the above features, i.e., continuous creation of matter and the value of deceleration parameter—were not major obstacles before the steady state theory. The cosmologists behind this model had a clear cut reply to those big bang cosmologists who criticize it for the continuous creation of matter: how can one believe in the violent creation of the entire matter in the universe at one instant $t = 0$ and criticize the relatively calm continuous creation? Likewise, everyone knew that there is considerable uncertainty in the measured value of deceleration parameter.

The greatest threat to steady state cosmology, however, came from another corner. This was the cosmic microwave background radiation discovered in 1965. The microwave background radiation can be considered as a 'fossil' in a universe which has evolution (such as the big bang model). Since the discovery of such a fossil will naturally lead to the falsification of the steady state model, Herman Bondi, true to his philosophy, declared that he is giving it up.

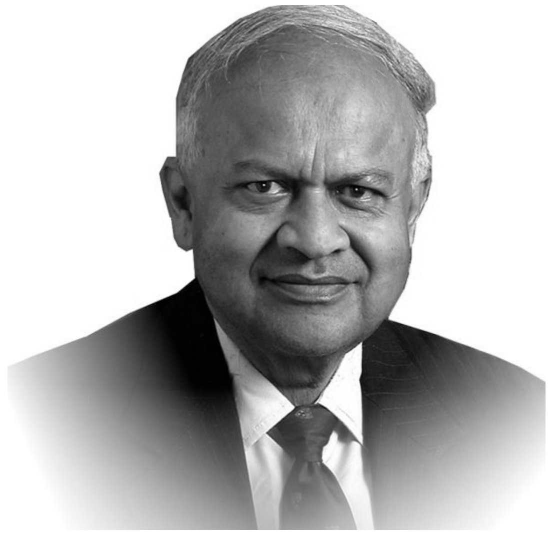
However, Fred Hoyle, Jayant Narlikar and Chandra Wickramasinghe, who were then working on the steady state model argued that the observed microwave background radiation may have other reasons to exist too. In some studies they published in 1967, it was found that the kind of iron 'whiskers' (very small needle-like grains of iron) that might have been produced in galaxies can absorb star light and can reemit them in microwave wavelengths. They pointed out that the amount of light observed in our own galaxy is of this order. That such iron whiskers can be produced in the high temperature zones around stars was proved experimentally in laboratories on earth itself. Weinberg has opined that this possibility cannot be negated outright. The Hoyle-Narlikar combine often ridicule those who argued that the production of iron whiskers is artificial for the arbitrariness of concepts such as dark energy and dark matter, on which big bang model had to rely lately, without any experimental evidence whatsoever.

In spite of all these, the discovery of the background radiation is really a success story for the big bang, for it was an important prediction in that model. At the same time, the steady state model as such does not predict it. For these reasons most people do like to view this radiation as a relic of a hot early universe, and thus, as a very strong evidence supporting the big bang model.

3. Jayant Narlikar

Looking backward, it may seem astonishing that in the growth of quantum mechanics in the first half of the twentieth century, there were major contributions from scientists in India, which was only a British colony at that time. Here are some examples. All the fundamental particles in nature can be divided into two categories, namely Bosons and Fermions. The former, which includes photons, the quanta of light, is named after the Bengali physicist Satyendra Nath Bose. It was he who discovered their collective quantum behavior. Similarly, Sir C.V. Raman, Meghnad Saha, etc., have made significant contributions to the development of quantum mechanics. But contrary to this, India has no names to project in the area of general theory of relativity during this period. Even S. Chandrasekhar, who wrote the 'horoscope' of stars, showed interest in general relativity only very lately, in the 1960s. The physics research in India shows this 'quantum leaning', in general. The first theorist who paved the foundations of general relativity in India was Prof. V. V. Narlikar, then a professor of mathematics at the Banaras Hindu University. Most of the general relativists in this country belong to the fold of Prof. V. V. Narlikar. His son, Prof. Jayant Narlikar, later shot to worldwide fame for his contributions to the steady state model.

Jayant Narlikar says that his desire to become a mathematician was not deliberately cultivated by his father. Here is an incident that took place while he was a student in standard three: The teacher asked each student what his/her parent is doing. Most of them were children of staff members of Banaras Hindu university. "My father is a professor" was Jayant's reply. "Professor of what?" the teacher again asked, but



Prof. Jayant Vishnu Narlikar

the child could not answer it. "Your father is a professor of mathematics" the teacher said. Narlikar remembers that the feeling of shame at not knowing the full answer soon gave way to one of elation, as his father is a professor of his best liked subject, which was mathematics.

Even then, he never forgets to acknowledge the ideal conditions he could enjoy in his pursuits. This humble professor attributes his success to the right people he had around him to support him in every matter. When he says that at $t = 0$ he was fortunate to have the right kind of parents, we recognize that the gentle humour in it is aimed at the big bang model!

In the 1960s, when Narlikar joined Fred Hoyle for research in cosmology, the big bang and steady state models were almost equals. But now in the midst of those who believe that the cosmic radiation discovered in 1965 has falsified the steady state model, there are only a few senior cosmologists including Narlikar who do not accept defeat. Among the criticisms they raise against big bang model, the most important is that this model does not provide a deep insight or revelation that triggers thought. The big bang simply follows an empiricist epistemology. The former students of Hoyle, namely Narlikar, Geoffrey Burbidge, Chandra Wickramasinghe, etc., have accused that even young researchers in cosmology do not hesitate to join the flock, without evaluating the situation objectively. The witty Burbidge had once qualified themselves as 'old revolutionaries' and the opponents as 'young conservatives' in cosmology!

After obtaining his Ph.D. in 1963, Narlikar started his career as a researcher and a professor in Cambridge and later in some of its allied institutions. At Cambridge, in order to cope with the fast changing situation on the observational and computational front in astronomy, Hoyle was feeling the need to set up an institution where visitors from active centres in the world would visit and discuss their work and thereby positively and constructively influence the working of academics there. When the response from the university and the government was not very forthcoming, private organisations such as Wolfson Foundation, Nuffield Foundation etc. came to support him. Finally when Cambridge University donated the necessary land for construction, Hoyle's dream project named 'Institute of Theoretical Astronomy' materialised. To what will happen to the institute when the Nuffield grant runs out, Hoyle replied that if the institute does not grow to a world class institute by that time, he for one would shed no tears at its abolition!

Narlikar was among the founding faculty in this institute. He got inspiration to start such an institution in India from this experiment. Narlikar opines that whereas institutions are created to boost egos of certain individuals, and continue long past their usefulness because no one has the courage to abolish them, the success of the institute justifies Hoyle's vision that such an institution was needed.

While returning to India in 1972, even though the steady state picture was fading, Narlikar was considered a national hero. Visiting India on an invitation from the President, he toured to make a series of lectures, delivered in his sharp and transparent style and attracted students and researchers to this new field. From 1972 to 1988 he worked as the Head of Theoretical Astrophysics at the Tata Institute of Fundamental Research (TIFR), Mumbai. This institute has by that time become a world renowned research institute under the able leadership of Homi J. Bhabha. Narlikar has disclosed that Bhabha's insights as to how to run a research institute has helped him a lot.

In 1988, the then University Grants Commission (UGC) chairman Prof. Yash Pal entrusted Narlikar with the task of establishing a world class institution for astronomy, astrophysics and allied subjects. On the outskirts of the Pune University Campus, by the side of the old Mumbai-Pune highway, the space for this was made available. Thus started the beautiful 'Inter-University Centre for Astronomy and Astrophysics' (IUCAA), designed by the world famous architect Charles Corrhea, hardly two kilometers from the Khadki railway station in Pune, which was formerly grasslands and small woods where cattle used to graze. Narlikar was its founder Director. Around a hundred researchers, many of them from abroad, stay and do research here. Many students and teachers from various Indian universities come to visit IUCAA quite often for interactions and references. Previously, any research grants for astronomy and astrophysics were given to individuals and university, college departments, directly by the UGC. But now a good chunk of it is spent through the IUCAA.

After being at the helm of action as Director for fifteen years, Narlikar is Professor Emiratus at IUCAA now. The most curious thing is that by this time the paradigm of steady state model is almost wiped out. In 1994, Hoyle, Narlikar and Burbidge together proposed the quasi-steady state cosmology (QSSC), a modified version of steady state model. In this new model, it is conceived that the universe oscillates, i.e., cycles of expansion and contraction repeats, even when it is in a steady state. We are now in an expanding phase of it. The model will have a hot past, just as in the standard big bang model. Thus it can explain the microwave background and other phenomena, without much difference from that of the big bang theory. Many people now consider it as not much different from standard big bang model, though they are not willing to test any difference with it at the observational front. Now the situation is such that after Shyamal Banerjee and Ram Gopal Vishwakarma, who helped Prof. Narlikar in his research in QSSC left for teaching assignments elsewhere, there are no research students working in this field at IUCAA.

Narlikar and Co., who were very much confident with QSSC, have expressed their annoyance that theories of science are not defeated; instead, they come to an end with the death or aging of their proponents. That the steady state model now provides a fossil that can be used for studies on the methodology of science is really an irony. Narlikar is disgusted by the plight of this branch of science, which is evident from his words. In an interview given to Frontline after his retirement, he said: “When I entered the field of cosmology as a research student in 1960, the subject was open and there were observational possibilities of checking theories. Today one relies on N-body simulations based on speculative initial conditions to assert what is the correct model of the universe. If I were a research student today, cosmology would not attract me.”

It would appear deliberate that none who spoke on the occasion of the send-off given to Prof. Narlikar mentioned his contributions to cosmology, and only mentioned his leading role in the establishment of IUCAA. He regrets that many people now use the theories developed by Hoyle and himself in the 1960s, such as negative energy scalar fields, black holes in galactic nuclei, superclusters and voids, oscillating universe which has no singularity, etc., without bothering even to acknowledge. Most are simply believers in big bang cosmology, though it is inconsistent with ground realities—even the measured value of the basic Hubble constant remains controversial. It is opposed to the spirit of science which asks for repeatable experiments to check a theory.

However, the role of Narlikar and coworkers in keeping cosmology a science is beyond mention. Prof. Richard Ellis, from Caltech in USA, says: “.. the reason why most astronomers believe in the big bang model is that it is the simplest picture that is consistent with the data. But it is very important that there are people who are constantly pushing to be provocative to make us question in more detail, whether this is the right picture or not”. Echoing similar views, E.P.J. van den Heuvel of the University of Amsterdam says: “It is very important that you have people like Narlikar who are exploring other possibilities. There is a lot that people do not basically understand. And it is now being told that with WMAP there are only a few details to be filled in and then we know everything. It is not like that. I do not believe that.” □

How light is created

Dr. A. K. Maiti*

LIGHT IS AT THE heart of our perception of the world. We see the world around us through the medium of light. The view of the blue sky, green trees, and red roses give us a sense of beauty; the yellow streak of a tiger warn us of danger; the light from the sun and the light from the stars give us the sense of what lies beyond the Earth. Naturally, light is essential for our existence as humans.

That is why a question naturally comes to mind: How is light created? This article is an attempt to answer that question.

Atoms and molecules absorb energy when an electron goes to a higher energy state (or excited state) and releases it when it comes back to the ground state, emitting light. Atoms or molecules can also be excited by electromagnetic (e. m.) radiation of higher energy to emit light of lower energy. For example, molecules excited by UV (invisible to human eye), may emit light in the visible range, which we can see. White light is a mixture of seven colours: violet, indigo, blue, green, yellow, orange, and red (VIBGYOR). When light is scattered by any object, the object is visible. The colour of the object is the colour that it scatters. The total range of wavelengths of e.m. radiation is from 0.1 Angstom to 1000 metre (Fig.1). Visible light is a small part of the total electromagnetic radiation range, from 400 nm (violet) to 700 nm (red). The human can not see electromagnetic waves outside this range.

There are other animals who can sense a larger range of wavelengths. Instruments are made to detect (called detectors) the whole range of e. m. radiation, including visible radiation. For example, the Photo Multiplier Tube (PMT) is a detector which can detect from UV to visible to IR range.

HOW LIGHT IS CREATED IN THE SUN OR A STAR

In the sun or any star, hydrogen atoms are fused together to form helium and in the process some mass is destroyed to produces a huge amount of heat. Due this heat, electrons of the hydrogen atoms are promoted to the higher energy states. When they return to the ground state, light is emitted at different wavelengths. The radiations at different wavelengths can be separated by means of a prism, to produce coloured bands, showing that the white light coming from the sun contains a continuous distribution of wavelengths. This is a characteristics of what is known as black body radiation.

An opaque and non-reflective body is called Black Body. The type of electromagnetic radiation emitted by a black body at constant temperature or the radiation emitted by a body in thermodynamic equilibrium with its environment is called black body radiation. A black body radiates continuous wavelengths. The intensity at different wavelengths depends only on the temperature of the black body. As the tem-

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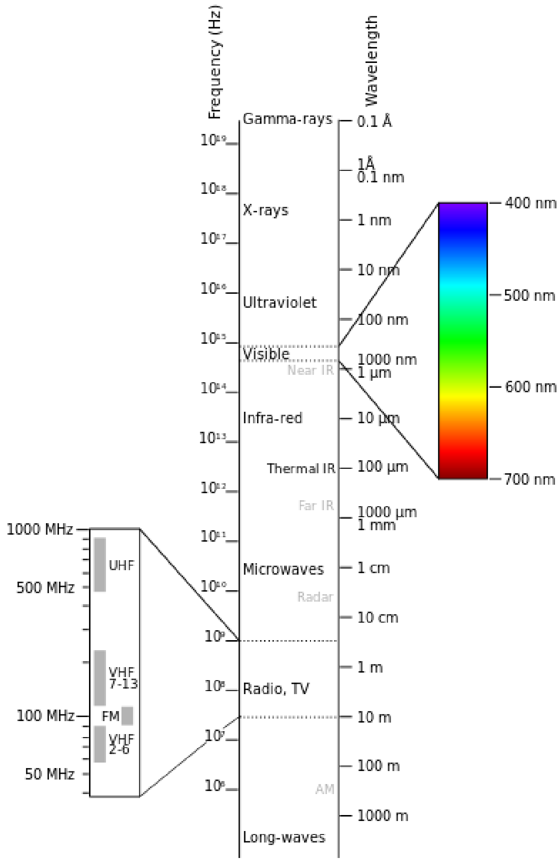

The frequency ranges of electromagnetic radiation.

perature decreases, the peak of the blackbody radiation curve moves to lower intensities and longer wavelengths. The light of continuous wavelength from the sun is essentially that of a blackbody radiator at 5780 K.

HOW LIGHT IS PRODUCED IN A FLAME

When we burn any material, cloth, grass, wood, oil etc., gases are emitted which are heated by the chemical energy generated during combustion. Electrons of the gas atoms are raised to higher energy level of the atom by the heat energy. Instantly the electron comes back to the ground state, emitting light. If the temperature of the gas is less, the electron will go to a lower energy excited state of the atom. When the electron returns to ground state it emits lower energy light (dull yellow flame). If the temperature of the gas is high the electron will go to higher energy excited state of the atom. In this case, when the electron returns to ground state it emits higher energy light (blue flame). So the colour of a flame is an indication of the temperature. Temperature of the yellow flame is much lower than that of a bright blue flame, but even the coolest flame is still very hot (at least 350 degrees Celsius).

LUMINESCENCE

When a molecule is excited by any form of electromagnetic wave (visible, UV, X-ray), the light emitted from the molecule is due to 'photoluminescence'. When it is excited by electrical energy, light obtained is due to 'Electroluminescence'. Similarly, when the molecule is excited by chemical energy it is called 'Chemiluminescence', and when excited by thermal energy, it is called 'Thermoluminescence', etc.

FLUORESCENCE AND PHOSPHORESCENCE

We differentiate luminescence, the light seen by us, as two types: fluorescence and phosphorescence. The electronic energy level of a molecule can be divided into singlet and triplet energy states. Electrons of the molecules in ground state are in the singlet state if their directions of spin are opposite. When electrons go to an excited state, if the spin in the excited state is in the opposite direction to that in the ground state, the excited state is also a singlet state. When light is emitted as the electron falls back to the ground state, the phenomenon is called fluorescence. But if the electron goes to an excited state where the spin is in the same direction to that in the ground state, the excited state is called ‘triplet state’. Electrons do not directly go to a triplet state from the ground state. Electrons first go to an excited singlet state from the ground state and then some electrons go to the excited triplet state, and some electrons jump back to the ground state. The ones that fall back to the ground state give rise to fluorescence. The triplet state is of lower energy than the excited singlet energy state. When electrons return back to the ground state from this triplet state, the light emitted is called phosphorescence.

Fluorescence is characterized by the life time of exited state (average time it stays in the excited state) which is in the range from pico-second (10^{-12} second) to nano-second (10^{-9} second) and phosphorescence is characterized by the life time of the excited state (milliseconds to a few hours). In most cases fluorescence emitted is of higher wavelength (lower in energy) than the energy of the absorbed radiation.

In case of fluorescence, if we turn off the exciting light the emissions stops almost immediately (within 10^{-9} second). In phosphorescence, after the exciting light is turned off, the substance continues to emit light for a long time, in some cases even for a few hours.

In a paper written in 1852, George Gabriel Stokes described the ability of fluorspar and uranium glass to change invisible light beyond the violet end of the visible spectrum into blue light. He named this phenomenon as fluorescence.

Fluorescence is a very sensitive method of detecting the presence of a substance in a sample. For a substance like di-sodium fluorescein it can detect even in concentrations as low as 10^{-13} gm/litre.

Fluorescence and phosphorescence are together called photoluminescence.

APPLICATION OF PHOTOLUMINESCENCE

There are many applications of photoluminescence:

1) In Canada there are two lakes which are separated by a few kilometres on the surface. But people had a hunch that they are connected underground. To test it, a small amount of a fluorescing molecule was sprinkled on one lake. A few days later, the water of the other lake was tested by a Photoluminescence Spectrometer. Fluorescence of the same molecule was detected. Thus, it was proved that, the two lakes are connected by underground.

2) Gemstones and minerals may have a distinctive fluorescence or may fluoresce differently under short-wave ultraviolet and long-wave ultraviolet. This property is employed in mineralogy, chemical sensors, fluorescent labeling, dyes and biological detectors. This property is also employed in commonly used fluorescent lamps.

3) There are many natural compounds that exhibit fluorescence, and have a number of applications. Some deep-sea animals, such as the green eye, use fluorescence.

4) Fluorescent paints glow when exposed to the long-wave ultraviolet frequencies (UV). These UV frequencies are found in sunlight and some artificial lights. This property is used for pavement marking and ultraviolet headlight.

5) Analytical chemistry: Many analytical procedures involve the use of a fluorometer, usually with a single exciting wavelength and single detection wavelength. Because of the sensitivity that the method affords, fluorescent molecule concentrations as low as 1 part per trillion can be measured.

6) Fluorescence in the life sciences is used generally as a non-destructive way of tracking or analysis of biological molecules by means of the fluorescent emission at a specific frequency where there is no background from the excitation light, as relatively few cellular components are naturally fluorescent (called intrinsic or autofluorescence). In fact, a protein or other component can be “labelled” with an extrinsic fluorophore, a fluorescent dye that can be a small molecule, protein, or quantum dot, finding wide usage in many biological applications.

7) The quantification of a dye is done with a spectrofluorometer and finds additional applications in forensics. Fingerprints can be visualized with fluorescent compounds such as ninhydrin. Blood and other substances are sometimes detected by fluorescent reagents, like fluorescein. Fibers, and other materials that may be encountered in forensics or with a relationship to various collectibles, are sometimes fluorescent.

ELECTROLUMINESCENCE

The common fluorescent lamp relies on fluorescence. Inside the glass tube is a partial vacuum and a small amount of mercury. An electric discharge in the tube causes the mercury atoms to emit ultraviolet light. The tube is lined with a coating of a fluorescent material, called the phosphor, which absorbs the ultraviolet and re-emits visible light. Fluorescent lighting is more energy-efficient than incandescent lighting elements.

CHEMILUMINESCENCE

White phosphorous produces greenish glow due to the oxidization of the element. This type of emission is known as chemiluminescence, where electrons go to excited state through a chemical reaction. Here phosphorous does not need any exciting light source for excitation of electron. It needs oxygen to glow.

PHOSPHORESCENCE

As we have seen, phosphorescence is the emission of light after excitation has stopped. The emission may continue even a few hours with lower intensity. The name “phosphorescence” is given to this phenomenon by mistake. Scientists found the similarity of the glow after excitation light is stopped with the glow of white phosphorous. That is why the name phosphorescence was given. But later it was found that phosphorescence is different from the glow of phosphorous (which does not need an exciting light but needs oxygen for the chemical reaction).

APPLICATIONS OF PHOSPHORESCENCE

1. Strontium aluminate based pigments are used in exit signs, pathway marking, and other safety related signage.

2. Phosphorescent materials are used for the glow-in-the-dark toys and clock dials that glow for some time in the dark after being exposed to any normal room light. The glow slowly fades in the dark room within a few minutes to a few hours depending upon the phosphorescent material.

3. Radium, a radioactive element was used long before for the glow of watch and other things in the night. But because of its health hazard due to radioactivity, it is no longer used for glow in the night.□

A Brief History of Science: Part 6: The Newtonian Synthesis

Soumitro Banerjee*

AS WE HAVE SEEN in the last installment of this article, the second half of the seventeenth century saw a rapid development in science. After centuries of slumber during the middle ages, people started taking a fresh look at nature with eyes unhindered by religious dogma. The mood of the time was probably best expressed by Hooke who insisted on the use of "a sincere hand, and a faithful eye, to examine and to record, the things themselves as they appear." "The truth is," wrote Hooke, "the science of nature has already been too long made only a work of brain and fancy: It is now high time that it should return to the plainness and soundness of observations on material and obvious things." The Royal Societies were formed in England and France, which acted as rallying points for the new breed of scientists. Excitement was in the air, and Boyle, Hooke, Wren, Halley, and many others made seminal discoveries which were presented and discussed in the Royal Society.

The contribution of Isaac Newton towers over everybody else of that period. His book "*Philosophiae Naturalis Principia Mathematica*" (Mathematical Principles of Natural Philosophy) had enormous influence on human thinking; it shaped the face of science for centuries to come. That is why it is necessary to understand the source of his inspiration — what determined the content and the direction of his scientific work. But the problem is confounded by the myths that have been built up around the personality of Newton: that he was an unsocial isolated eccentric genius; that the fall of an apple on his head caused the discovery of the theory of gravitation, etc. We need to unearth the reality by removing the veils of such common misconceptions.

The history of science is a part of world history. And there are two points of view in looking at world history. One point of view sees history as a chronological account of the kings' ascent to power, conflicts between kings and kingdoms, the rise and fall of empires, and the gallantry and heroics of kings and their generals. This is how history is taught in our schools and colleges. This is not a scientific viewpoint of history, because, while the focus is on the events of the past, the underlying social processes that determine the course of events are obscured from view. A scientific view of history, on the other hand, focuses on the peoples' life and livelihood, and the development of the productive forces in the different epochs, as reflected in the peoples' livelihood. The social factors underlying the major developments in history are then understood in terms of the conflict between the productive forces and the production relation prevailing in each phase in history. This is how we understand the transition from a hunting-gathering society to slavery,

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from slavery to feudalism, and from feudalism to capitalism. The kings and emperors who ruled in these periods are important, but are not central to the understanding of the course of history.

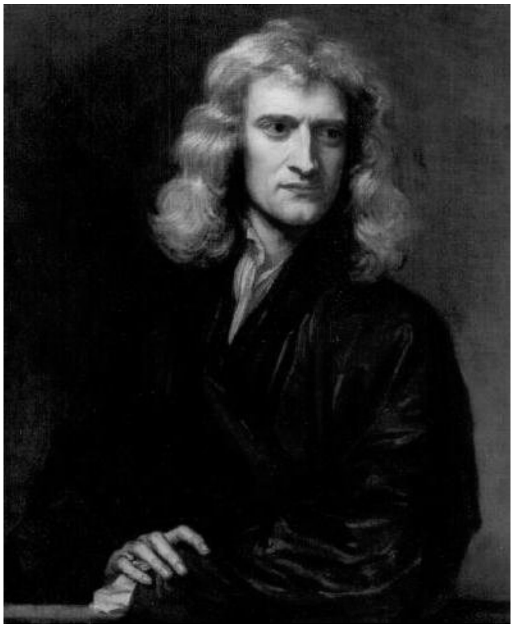
That is why, in order to understand the motivation behind Newton's scientific work, we have to look at the development of the productive forces in that period of time, and the scientific problems posed by it.

The development of the productive forces

What was the social condition in the period preceding Newton's time? In the earlier installments of this article we have seen that it was a time marked by the transition from the feudal middle ages to a new capitalist form of production. The merchant class that developed within the womb of the feudal society was becoming financially powerful, and was starting mass-production of goods in "manufactories". Initially these were simply sheds where a number of artisans together produced goods using the raw material and implements supplied by the merchant. But slowly, through the 16th and 17th centuries these manufactories became bigger, produced larger quantities of goods, and consequently the financial and political power of the producers increased.

The increase in production posed a few scientific problems. The goods had to be sent to distant lands for trade and commerce. But in those times, land transport was very rudimentary. The ox-drawn carts could not carry much load, and were very slow. In comparison, waterborne transport in barges, ferries and ships could carry far more goods, and was much faster. That is why the focus of that time was in improving waterborne transport. This demanded improved design of the ships, and for that one had to know the laws governing the motion of floating bodies. The tonnage capacity of the ships could be calculated only if one knew the quantity of water it displaces at different depths of submergence. While maritime transport was the preferred mode for reaching one country from another, river-based transport was the preferred mode for goods transport within a country. In addition, to increase the reach of inland transport, an elaborate system of canals was developed. The design of efficient canals and lock-gates demanded knowledge of the rules governing the flow of liquids through channels and cavities of different cross sections. Thus, waterborne transport posed various problems in hydrostatics and hydrodynamics.

An important problem in maritime transport was the problem of determining a ship's position in open sea. The position is specified by the latitude and longitude. Determining latitude was relatively easy: it could be found from the altitude of the sun at noon (i.e., at its highest point), if one has a pre-calculated table giving the sun's declinationfor the day at different latitudes. But the determination of longitude posed a tough scientific challenge. Until the solution of the problem was found, the ships had to move close to the shore, and thus had to travel much longer distances to reach the destination. People realized that the problem of determination of longitude is essentially the same as that of determination of the time at a given location, relative to the time at a "standard" location. A way of finding the time was through the observation of the bodies in the sky — the moon, planets, and stars. Thus, preparation of the catalog of the positions of these heavenly bodies became a matter of practical importance, and in most of the seafaring nations observatories were established with the express objective of preparing the charts of the positions of these heavenly bodies. Some of these bodies, like the moon and the planets move, and hence it became



Isaac Newton (1642-1727) at a young age.

necessary to know the laws governing their motion. Scientific attention was thus directed to the objects in the sky, and their motion.

In this period the struggle between the old kings, nobles and aristocrats, and the emerging bourgeois class took the form of armed fight for supremacy. As a result, warfare increased in number as well as in intensity. The demands of warfare also posed important problems before science. Firearms and cannons were already in use since the thirteenth century. For effective use of the firearms it became necessary to know the process that takes place when gunpowder is ignited. Why does a gun recoil, and by how much? At what angle should the cannon be inclined so that the cannonball can hit the target at a given distance? What is the trajectory of a bullet after it is fired? What is the effect of air resistance on the trajectory? Solution of these problems demanded the development of mechanics.

The necessities of larger volume of production needed ever larger quantities of metals — especially iron and copper. Increased warfare only increased the demand of metals. Thus mining came out of the old "craftsmen" character and became a major industry. Deeper and deeper mines had to be explored in order to reach the right kind of ores. This again posed important scientific problems. Water had to be continuously pumped out of the mine chambers. The mines had to be ventilated by pumping in air. The ore had to be transported out of the mine. The metallic iron and copper had to be extracted from the ore. These are problems of mechanics and chemistry. The excavation of the mine chambers and the connecting tunnels also needed a good idea of solid geometry.

In those days the main medium of exchange in trade was gold. The increase in the volume of trade needed ever larger quantities of gold. The gold mines of Europe were soon exhausted, resulting in a "gold famine". This was one of the reasons behind the royal patronage of the expeditions to distant lands. The gold famine also resulted in a great interest in alchemy — the forerunner of chemistry — because at that time it was believed that it was possible to turn other metals into gold using chemical processes.

Thus we see that the rapid development of productive forces in the period following the renaissance posed important scientific problems — in mechanics, hydrostatics, hydrodynamics, mathematics, and chemistry. But, out of all these, the most profound questions concerned mechanics, which absorbed the attention of scientists of that time. The further development of the productive forces crucially depended on the solution to these scientific problems.

Age of reason — personified: the life of Isaac Newton

It is a common belief that the making of a genius requires a complacent childhood, favourable hereditary tracts, and guidance and financial resource of parents. In this yardstick nobody would expect Newton to be what he was. His life confirms that every man is a product of his own struggle, and the people whom we call genius are more so.

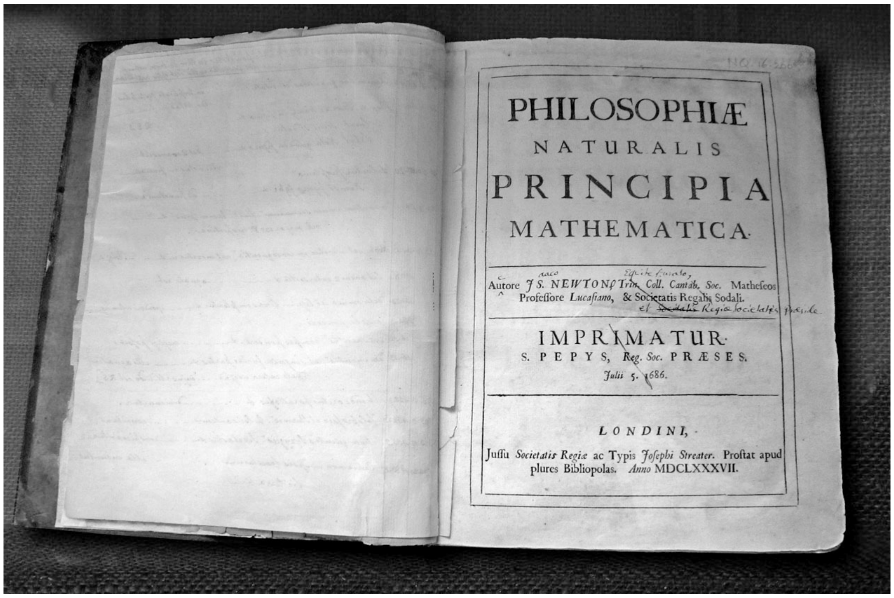
Isaac Newton was born on December 25, 1642 (the year Galileo died) in the village of Woolsthorpe, England. His father, who died before Newton's birth, was a farmer of moderate means. Newton descended from common men on both sides; there is no record of any notable ancestor.

Newton's mother remarried and left her three year old son with his grandmother. At the age of twelve Newton was sent to school at Grantham. Here, during his leisure hours, he constructed a number of innovative mechanical toys including a water clock, a mill (powered by a mouse), and many sun-dials (one of which still survives). In 1656 Newton's mother was widowed again and Newton was called home to help with the farm at Woolsthorpe because of the family's financial crisis. He proved to be useless in taking care of sheep, and was sent back to school, and in 1661, at the recommendation from his uncle, he proceeded to the University of Cambridge for further studies.

In those days the custom was that the students from poor families had to work as servant (called a subsizer) to students from richer families. Newton had to work as a subsizer at the university to make both ends meet. His academic record in his undergraduate years seems to be outwardly undistinguished. However, these were the years of formation of his scientific being and he waged a serious struggle to inherit the contemporary philosophical cross-currents and scientific ideas. From the critical notes in his notebooks, researchers have concluded that in these years he thoroughly studied Aristotle's "Organon" and "Ethics", Euclid's "Elements", Galileo's "Dialogo", Descartes' "Geometrie" and "Principia Philosophiae", and other important books on philosophy and science. From these studies he developed his own personal viewpoint in the matter of scientific investigation, and it seems the mathematical approach of Descartes has profound effect on his thought process.

In 1665, an outbreak of plague caused the universities to close and Newton returned to his home in the country, where he remained till 1667. There, in the two years of rustic solitude — age 22 to 24 — his creative genius burst forth in a flood of discoveries unsurpassed in the history of human thought: the binomial series of negative and fractional exponents, the differential and integral calculus, universal gravity as a key to the mechanism of the solar system, the splitting of sunlight into the visual spectrum by means of a prism — with its implication of understanding the nature of light, etc. He was a very cautious man in the matter of scientific work, and did not want to make his discoveries public until he obtained definitive experimental evidence confirming his analytical work. Yet, his mathematical abilities were so evident that his teacher Prof. Isaac Barrow resigned his Lucasian Professorship in 1669 and Newton was offered the post at the age of 27.

He initially conveyed his discoveries on the nature of light and colours to the Royal Society. But soon he retreated into his shell because some criticisms were raised when his communications were read at the Royal Society meetings. He kept working, performing experiments, checking his conclusions. Then in 1684 a meeting with Hal-



A surviving copy of the Principia Mathematica.

ley changed all that. By then Halley had come to the conclusion that there must be a central force acting on the planets, but at that time nobody had been able to work out the orbit of the planets starting from that premise. He asked Newton what would the trajectory of a planet be, if it is acted on by a central force of the inverse square type. Newton answered, simply, that it would be an ellipse. “How do you know?” “I have calculated it.”

Halley was flabbergasted. This man knows the answer to a question everybody is looking for, and yet he has not published it? He urged Newton to let the world know about his calculations. This prompted Newton to embark on a grand plan to write down everything that he has obtained in the area of mechanics into a single book. This took an almost inhuman effort, working day and night for two years. Finally when it was published in 1687, the Principia Mathematica went on to become one of the books that changed human history.

The Principia Mathematica

The Principia Mathematica was written in an abstract mathematical language. This could not be otherwise, because Newton's intention was to tell the world how the problems of the day could be solved by assuming a few “laws” of nature, using the techniques of mathematics. Still he took care to be intelligible to the learned people. Even though he had arrived at most of the results using the technique of calculus which he invented, he never used calculus in his expositions. Instead, he took pains to derive the same results using the methods of geometry which the learned people of that time were familiar with.

The Principia Mathematica is written in three volumes. In the first volume Newton clearly defines the terms to be used in the exposition[1], and then states the laws of motion. Thus, he lays the groundwork

[1]Here he adheres strictly to the demands of formal logic.

on the basis of which the theoretical framework will be built.

The second volume is devoted to the application of these laws to achieve the solution of mechanical problems related to the movement of bodies. He treats motion of bodies in resistive medium (this solves the problem of ballistics, and has direct implication in warfare), the motion of floating bodies and hydrostatics (this formed the theoretical basis for the design of ships), the compression of gases and liquids under pressure (recall the problems posed by mining), movement of liquids in channels and tubes (theoretical foundation for the design of canals, locks, and water pumping equipment), and the movement of pendulums against frictional resistance (this had implication for the construction of pendulum clocks), etc.

The third volume of Principia is fully devoted to what he calls "System of the World". Based on the laws of motion and the theory of universal gravitation, he explained the observed motion of the planets, proved Kepler's laws, explained why tides occur, and showed how one can predict the position of the moon and the planets at any time in the future. This not only had immense importance in navigation, as we shall soon see, it completely changed the way scientists perceived nature.

Thus we see that the problems posed by the contemporary society and the development of the productive forces supplied the subject matter of Newton's line of thinking. The picture of Newton's character as an isolated genius, unconcerned about the society, discoveries sparked by falling apples — these are simply myths propagated by people who have failed to understand the content of Newton's work because of the abstractness of his exposition and the absence of direct reference to the above practical problems.

It is always found in the history of science that, whenever the society is ready for certain development of ideas, usually a number of people would be working on each idea at the same time. We have seen that at that time the society posed certain scientific questions, and the further development of the productive forces crucially depended on the solution of these problems. In that situation it is natural to expect that many people would be contemplating the solution of each problem at the same time. That is exactly what had happened. The Royal Society records show that many people at that time were working on the problems of hydrostatics, hydrodynamics, and mechanics. In fact, both Hooke and Halley had realized that the motion of the planets must be under the action of a central force, and guessed that the force would follow an inverse square law. But, they could not prove that a force that goes as the inverse square of the distance between two objects would mathematically imply the Kepler's laws of planetary motion. Hooke and Newton were working on optics, the theory of colours, and the nature of light at the same time, and had reached different conclusions. While Hooke saw light as a wave, Newton favoured a corpuscular theory of light. Newton and Leibniz developed the methods of calculus at the same time.

In such a situation it is not unnatural to see debates between scientists on the content of the discoveries, and controversies concerning who discovered something first. Today, the primacy of a discovery is decided on the basis of who communicated a discovery to a scientific journal first. At that time there were no scientific journals or system of recording the date when a paper is communicated, and so it was difficult to settle the claims. Mostly the scientists made the discoveries while working away from each other, and so it was impossible to ascertain who made a discovery first. The disputes between Newton and Hooke on the nature

Robert Hooke (1635-1703). Artist's impression, drawn at a later time.

of light, and that between Newton and Leibniz on the primacy of the discovery of calculus should be seen from this angle. It may be true that each piece of idea may have been worked out by different people at almost the same time, but there is no denying that it was Newton who achieved the grand synthesis — to create a system of knowledge which was to form the basis of scientific thinking for centuries to come.

There is another aspect worth keeping in mind when evaluating the contribution of Newton. We have seen that Newton's time immediately followed the renaissance in Europe. We have seen in the last installment that, through the period of the renaissance, people like Galileo, Bacon, and Descartes charted out a new path of doing science. The change happened with incredible swiftness: Copernicus' book was published in 1543, Galileo died in 1642, and Newton was born in the same year. Thus, after a millennium of unquestioning submission to religious dogma, the "age of reason" took root in a section of the people within a short span of only a hundred years. But the majority of the population was still under the spell of the Church — Catholic as well as Protestant. Religious obscurantism, bigotry, and blind beliefs were still ruling the minds of the common people. Only among a section of the learned people the seed of doubt had been sown about the correctness of beliefs propagated by the Church. The central belief that everything in the world is created and controlled by God was till intact. The universities were still centres of dry scholasticism.

Thus, in those tumultuous times, old religious values were still very strong; the new outlook based on reason had taken birth, and was in struggle with the old. Every man's thought process is built by absorbing the cross-currents of thought existing in the contemporary society. So was Newton's. Many commentators have not even tried to understand this aspect, and have made Newton's religious belief a focal point in their evaluation. We have to understand that this contradiction in Newton's personality was only normal. The philosophical ground for the emergence of a secular mind completely devoid of religious influence had not yet been created in Europe's intellectual atmosphere. The evaluation of any great man has to be done on the basis of which philosophy — the old backward-looking line of thought or the newly emerging line of thought — is reflected in a greater measure in his work. Seen from this angle we find that the newly emerging age of reason had its best personified expression in Newton.

Why Newtonian mechanics dealt a blow to idealism

What is the essential content of Newtonian mechanics? Since time immemorial people had seen motion of bodies — the motions of the sun, moon and the planets, the motion of an arrow released from a bow, etc. But in the ancient time people did not know the reason behind the motion of material bodies. So they assumed a supernatural

Gottfried Wilhelm von Leibniz (1646-1716).

hand behind every motion. They thought that God makes the sun, the moon, and the planets move. They even saw a divine hand deciding the path of an arrow released from a bow. This is because, following Aristotle's theory, people thought force produces motion. Thus, wherever they saw motion, they assumed the existence of some entity continuously applying force.

Galileo showed that force does not produce motion; force in fact produces a *change in motion* — what we know today as acceleration. Newton made it his first law — "unless acted upon by an external force, a body will continue in uniform rectilinear motion in a straight line." This told people not to look for something applying a force whenever they saw motion; and to look for it only if they saw change in motion. Thus the role of God in causing all sorts of motion became truncated.

But we do see many instances of change of motion in the bodies around us. The motion of the moon around the Earth is an instance where change of motion is taking place at every instant. Who is applying the force in this case? Newton showed that gravitation — a universal property of matter — is responsible for it, and that it follows a definite mathematical rule. Thus the application of this force does not depend on the will of God. The role of God became further restricted.

Then Newton showed that if a force is applied, the change in motion of any body also follows a definite mathematical rule: force = mass $\times$ acceleration. Using this rule one can obtain a differential equation for the motion of any body. Now, if we know the initial condition of motion of the body (like the initial position and velocity), then one can solve the differential equation to obtain the condition of motion at any time in the future. He showed that the motion of the planets, comets, arrows, and cannonballs can be predicted by application of this method.

This implies that there is no role of the God in the motions of the planets and other "heavenly" bodies. Man can calculate their future positions using the method proposed by Newton. The motion of cannonballs and arrows would simply be parabolas — these may only deviate a bit from the parabolic paths due to air friction. Newton also showed by how much they would deviate. Thus there remained no role for God in any type of motion.

After being eclipsed by idealism for millennia, materialism made a forceful comeback in the sphere of philosophy. This is what set the agenda for science for centuries following Newton. And this is the historical importance of Newton and his Principia Mathematica.

The emergence of mechanical materialism

Due to the influence of religious philosophy, many people could not digest the role of God becoming so insignificant in their picture of the world. They agreed that if something is in motion it will always remain in motion unless acted upon by an external force. But they asked, who created motion for the first time? Who gave the first impulse? They pictured this as the role of God: giving the first push and setting the universe in motion. Thus came the concept of a "Prime Mover". Due to his own religious belief, Newton himself sided with this position. This was the limitation of the time: the stage was not yet set for the emergence of a truly secular world-view. That situation emerged only in the nineteenth century when the idea emerged that there can be nothing in absolute rest, without any motion. Matter exists means it exists in motion. Therefore it is unscientific to think that initially all matter was at rest, and at some point of time somebody injected motion into it. It is now understood that motion is a mode of existence of matter.

Newtonian mechanics created a new picture of the universe, where everything is in motion following the fixed laws. The stars and planets are moving in specific orbits obeying the laws of motion, like the hands of a clock. In this mental picture the whole universe looks like a gigantic machine. The motion of each specific body is like that of a part of the machine — each part moving in its own course, following fixed rules. This line of thinking gave birth to a philosophy which is in nature materialistic, and in that sense it worked towards freeing people from many obscurantist ideas and misconceptions, but its form was mechanical. The historical importance of this philosophical trend, known as mechanical materialism, was that it again brought materialism to the centre of current thought. □

Scientific Ideas: Their Origin and Effects

Max Planck

It will be well to begin with some words of explanation on the subject of the present paper. The origins and effect of scientific ideas may seem a somewhat general and also a somewhat arrogant theme; it might even be suggested that it would be have been better had I confined myself to the ideas of natural science. Yet if I had so confined myself the ideas with which I propose to deal would have been restricted in a manner which I consider unnecessary and unnatural. Looked at correctly, science is a self-contained unity; it is divided into various branches, but this division has no natural foundation and is due simply to the limitations of the human mind which compel us to adopt a division of labour. Actually there is a continuous chain from physics and chemistry to biology and anthropology and thence to the social and intellectual sciences; a chain which can not be broken at any point save capriciously. Again, the methods used in the various branches are found, if closely considered, to have a strong inner resemblance, and if they appear to differ, it is only because they have to be adapted to the different subjects which they treat. This inner resemblance has become more and more evident in recent times, to the great advantage of the whole of science. Hence I consider myself entitled to begin with considerations applying to the whole of science; although of course when I pass to more particular applications. I shall tend to confine myself to my own subjects.

Let me begin by asking how a scientific idea arises and what are its characteristics. In asking these questions I cannot attempt, of course, to analyse the delicate mental processes taking place in the investigator's mind and what is more, largely in his subconscious mind. These processes are mysteries which can be revealed only to a limited extent if at all, and it would be equally foolish and rash to attempt any study of their inmost nature. The most that we can do is to begin with the obvious facts, which means that we investigate those ideas which have actually proved their leavening force for any branch of science; and this in turn means that we ask in what form they first occurred and what was their content at that time.

The first result of such an investigation is the discovery of the following rule: any scientific idea arising in the mind of a scholar is based on a concrete experience, a discovery, an observation, or a fact of any kind, whether it is a physical or an astronomical measurement, a chemical or a biological observation, a discovery among the archives or the excavation. The content of the idea consists in this experience being compared and being brought into contact with certain different experiences in the mind of the scholar, in other words, in the fact that it establishes link between the old and the new, so that a number of facts which had hitherto co-existed loosely are now definitely inter-related. The idea becomes fruitful and hence attains value for science if the interconnection thus established can be applied more generally to a series of cognate facts; for the establishment of an interconnection creates order and order simplifies and perfects the scientific view of the universe. What is most important, however, is that the task of applying the new idea in its entirety shall lead to new questions and hence to new studies and to new success. And this is true of the physicist's hypotheses no less than of the interpretations established by the philologist.

I propose now to exemplify the above in some detail, and in doing so I desire to confine myself to my own subject of physics. The angle of vision may appear somewhat restricted; on the other hand I shall be able to throw a clearer light upon the subject.

A classical example of the sudden emergence of a great scientific idea is found in the story of Sir Isaac Newton who, sitting under an apple tree, was reminded by a falling apple of the movement of the moon around the earth and thus connected the acceleration of the apple with that of the moon. The fact that these two accelerations are to each other as the square of the radius of the moon's orbit is to the square of the earth's radius, suggested to him the idea that the two accelerations might have a common cause and thus provided him with a foundation for his theory of gravitation.

Similarly, James Clerk Maxwell, on comparing the strength of a current measured electromagnetically, with the strength of a current measured electrostatically, found that the ratio between these two magnitudes agreed numerically with the speed of light, and thus formed the idea that electromagnetic waves are of the same nature as light waves. This agreement became the starting-point of his electromagnetic theory of light.

We thus find that it is a characteristic of every new idea occurring in science that it combines in a certain original manner two distinct series of facts; and this can be traced in every instance, though certain differences occur with regard to content and formation. These differences in turn bring about differences in the effect and the fate of the different scientific ideas. Some of them eventually become the common property of science, are taken for granted, and cease to be stressed. Such has been the fate of the two ideas just mentioned: of Newton's idea about the similarity between the acceleration of the moon and the gravitational accelerations on earth; and of Maxwell's idea about the electromagnetic nature of light. It is true that a good deal of time had to elapse before the later idea won acceptance; at first, it tended to be disregarded, especially in Germany, where Wilhelm Weber's theory, which was based on the assumption of immediate action at a distance, held the stage. It was not until Heinrich Hertz made his brilliant experiment with ultra-rapid electric oscillations that Maxwell's theory obtained the recognition it deserved.

Other ideas which have become the lasting heritage of science are those which hold that sound waves are of a mechanical nature and that rays of light and heat are identical. Teachers of physics tend to deal all too briefly with these ideas, and they should be reminded that there was a time when these ideas were far from being commonplace. The second of the two just mentioned was indeed for years the subject of fierce controversy. It may be mentioned as curiosity that the scientist whose experiments contributed most to its success—the Italian physicist Macedonio Melloni—began by being one of its opponents, an instructive example showing that scientific values are independent of their theoretical interpretation.

From the pages of history

But most of the ideas which play a part in science are different from those enumerated. The latter were perfect when they first took shape and will always retain their validity unchanged; those others assume their final form gradually, retain their value for a time and eventually either die or are modified to a more or less considerable degree. Frequently enough they resist modification and this resistance tends to be obstinate in proportion to their past successes: there have been occasions when this resistance has sensibly hampered the progress of science. Physics offers some instructive examples which it may be worthwhile to discuss in detail.

I propose to begin with the idea of the nature of heat.

The first stage in the development of the theory of heat consisted in calorimetry. It was based on the assumption that heat behaves like a delicate substance which flows from the hotter to the colder body whenever there is contact between two bodies having different temperatures. No quantitative change is supposed to take place during this process. This hypothesis worked well so long as no mechanical effects entered into play. A difficulty consisted in the production of heat by friction or compression, and this it was sought to overcome by assuming that the capacity of bodies for heat was variable, so that heat could be pressed out of a body under compression, like water being pressed out of a wet sponge, during which process the quantity of water remains unchanged. Later, when the invention of heat utilizing power systems made more urgent the question of the laws governing the production of mechanical work from heat, Sadi Carnot tried to formulate the production of work out of heat on the analogy of the production of work out of gravity. As the falling of a weight from a greater to a less height can produce work, so the transition from a higher to a lower temperature can be used for the same purpose; and as the work obtained from gravitation varies as the weight of the body and the difference in height, so the work produced by heat varies as the amount of heat transferred and the difference in temperature.

This materialist theory of heat received a shock from the empirical fact that a body's capacity for heat remains practically unaffected by compression and by friction; and it was finally refuted by the discovery of the mechanical heat equivalent, the significance of which consists in the fact that heat is dissipated in friction and new heat is produced in compression. The older theories of heat were thus reduced *ad absurdum* and it became necessary to build up a new theory. This task was undertaken by Rudolf Clausius and it was fulfilled in a number of classical works in which the second main principle of thermal dynamics was established. This principle purposes that there are irreversible processes, i.e., processes which cannot in any way whatever be reserved. Now the conduction of heat, friction, and diffusion are among these processes.

Carnot's theory to the effect that the transition from a higher to a lower temperature was analogous to the falling of a weight from a higher to lower level was not, however, to be so easily refuted. There were physicists who considered Clausius's ideas unnecessarily complicated and vague and who objected particularly to the introduction of the idea of irreversibility, by which a unique position among the various kinds of energy was assigned to heat. Accordingly, they formed the theory of energetics in opposition to Claudius's thermo-dynamics. The first principle of this theory agrees with that of Claudius in enunciating the preservation of energy; the second principle, however — that which indicates the sense of events — postulated a thoroughgoing analogy between the transition from a higher to a lower temperature and the falling of a weight from a higher to a lower level, or again, the passing of electricity from a higher to a lower potential. Hence it came about that irreversibility was declared superfluous in order to prove the second principle, and that the existence of an absolute zero was denied, it being pointed out that temperature resembled levels of height and levels of potential in that only differences and nothing absolute could be measured. The fundamental distinction which consists in the fact that a pendulum swings past the position of equilibrium before coming to rest and that a spark passing between two conductors having opposite charges oscillates, whereas there is no such thing as an oscillation of heat between two bodies between which heat is passing, was considered irrelevant by the energetist school and was passed over in silence.

I myself experienced during the 80's and 90's of the last century what are the feelings of a student who is convinced that he is in possession of an idea which is in fact superior, and who discovers that all the excellent arguments advanced by him are disregarded simply because his voice is not powerful enough to draw the attention of the scientific world. Men having the authority of Wilhelm Ostwald, Georg Helm, and Ernst Mach were simply above argument.

The change originated from a different side altogether: atomism began to make itself felt. The atomic idea is extremely old; but its first adequate formulation took shape in the kinetic gas theory which originated more or less contemporaneously with the discovery of mechanical heat equivalent. The energists first opposed it vigorously, and it led a modest existence; towards the end of last century, however, experimental investigation led to its rapid success. According to the atomist idea the transference of heat from the hotter to the colder body does not resemble the falling of a weight; what it resembles is a mixing process, as when two different kinds of powder in a vessel, having first constituted different layers, eventually mingle with each other if the vessel is continually shaken. If this happens the powder does not oscillate between a state of complete mixture and complete isolation of the constituent powders; what happens is that the change takes place once in a certain sense, viz. in the direction towards complete mixture, and is then at an end: the process is an irreversible one. Seen in this light the second principle of thermo-dynamics is found to be of a statistical nature: it states a probability: the arguments supporting this view and indeed raising it beyond any doubt have been well stated by my colleague, Max Von Laue.

The historical development here described may well serve to exemplify a fact which at first sight might appear somewhat strange. An important scientific innovation rarely makes its way by gradually wining over and converting its opponents: it rarely happens that Saul becomes Paul. What does happen is that its opponents gradually die out and that the growing generation is familiarized with the idea from the beginning: another instance of the fact that the future lies with youth. For this reason a suitable planning of school teaching is one of the most important conditions of progress in science. Accordingly, I should like here briefly to deal with this point.

What is learnt at school is not as important as how it is learnt. A single mathematical proposition which is really understood by a scholar is of greater value than ten formulae which he has learned by heart and even knows how to apply, without, however having grasped their real meaning. The function of a school is not so much to teach a business-like routine as to inculcate logical and methodical thought. It may be objected that ultimately it is the ability to do things rather than knowledge that matters; and it is true that the latter is valueless without the former, just as any theory is ultimately important only by reason of its particular applications. Yet routine can never be a substitute for theory, for in any cases that fall outside the rule, routine breaks down. Hence the first requisite, if good work is to be done, is a thorough elementary training; and here it is not so much the quantity of facts learned as the manner of treatment that matters. Unless this preliminary training is acquired at school, it is hard to obtain it at a later stage: training colleges and universities have other tasks. For the rest, the last and highest aim of education is neither knowledge nor the ability to do things, but practical action. Now practical action must be preceded by the ability to act, and the latter in turn demands knowledge and understanding. The present age, which lives at such a rapid rate, and shows so much interest for every innovation having an immediate sensational effect, provides us with instances where scientific training tends to anticipate certain exciting results before they have properly ripened; for the public is favourably impressed if the curriculum of an intermediate school already contains modern problems of scientific investigation. Yet such a practice is exceedingly dangerous. The problems cannot possibly be dealt with thoroughly, and the consequence may easily be to induce a certain intellectual superficiality and empty pride in knowledge. I should consider it extremely dangerous if the intermediate schools were to deal with the theory of relativity or the quantum theory. Specially gifted scholars always require exceptional treatment; but the curriculum is not designed for such, and I would definitely condemn any attempt to take such a question as that of the universal validity of the principle of the preservation of energy—which, of course, to-day is seriously regarded as an open one in nuclear physics—and to treat it as debatable before pupils who cannot have properly grasped the meaning of the principle involved, much less its potential scope.

The results of such an up-to-the-minute method of teaching become all too plain when we consider the way in which the breakdown of the exact sciences is occasionally spoken of to-day. It is characteristic of the prevalent confusion that there are numbers of inventive minds busying themselves to-day upon devices which aim at the unlimited production of energy or the utilization of the fashionable mysterious "earth rays". And it is even more surprising that credulous persons provide ample funds for such inventors, while really valuable and hopeful scientific investigations are hampered or actually stopped by lack of means. A through school training might here prove a useful remedy, and this would apply to the patrons no less than to the inventors.

After this educational digression I should like briefly to deal with another physical idea whose varying fate may prove even more instructive than the changes undergone by the theory of heat. What I have now in mind is the idea of the nature of light.

The study of the nature of light began with the measurements of the speed of light. The idea which led Newton to his emanation theory established a comparison between a ray of light and a jet of water; the velocity of light was compared with the velocity of particles of water flying in a straight line. This hypothesis, however, failed to give an account of the phenomenon of light interference, i.e., of the fact that two rays of light meeting at a point can in certain circumstances produce darkness at that point. Accordingly the emanation theory was given up and its place was taken by Huygens' theory of undulations, where the underlying idea is that light is propagated like a wave of water which spreads concentrically in all directions from its point of origin at a velocity which, of course, is not connected in any way with the velocity of the particles of water. This theory succeeded completely in accounting for the phenomena of interference: two waves on impinging on each other can cancel each other whenever the crest of one wave impinges on the trough of another. However, this theory, too, did not last longer than a century. The undulation theory failed to explain the effect at a great distance of a ray of light having a short wave length. The intensity of light decreases as the square of the distance, so that if light is radiated equally in all directions it is impossible to understand how a ray is capable of producing, even at a very great distance, a quantity of energy which is entirely independent of its intensity, and which is relatively very considerable in the case of short waves like those of Röntgen rays or Gamma rays. Such powerful effects combined with extremely feeble intensity become intelligible only if we imagine the energy of light to be concentrated upon distinct, unchangeable particles or quanta. In a sense, this is a return to Newton's hypothesis of light particles.

At present, then, the position is an exceedingly unsatisfactory one. We have two theories facing each other like two equally powerful rivals. Each possess keen weapons, and each has a vulnerable spot. It is hard to foretell the ultimate issue, but it is probably correct to say that neither theory will prove completely victorious. It is more likely that in the end a higher standpoint will be reached, where we shall be able to survey clearly the claims and the deficiencies of each of the two hypotheses.

Such a standpoint can probably be found only if we intensify our search for the source of all experience, which would mean in the present case that we would turn our attention to the measurement of optical phenomena. This in turn would imply that we would turn our investigation upon the actual measuring instruments, a step which, in principle, is of enormous importance since it may be described as the introduction of totality into physics. According to this principle the laws of an optical phenomenon can be completely understood only if the peculiarities of the process of measurement are studied as well as the physical events at the points where the light originates and spreads. The measuring instruments are not merely passive recipients simply registering the rays impinging upon them: they play an active part in the event of measuring and exert a casual influence upon its result. The physical system under consideration forms a totality subject to law only if the process of measuring is treated as forming part of it.

Is it at all possible to predict with confidence the mutations of any scientific idea? Is it possible to claim that there is so much as an approximate law governing the development of scientific ideas? Looking back on the historical development of events one is tempted to suspect such a law, on considering that many important ideas began by existing in the dark, uncomprehended by the many and at best dimly foreseen by a few students who were in advance of their age; but that once mankind had become ripe for them, they came to life suddenly and simultaneously in a number of different places. The principle of the preservation of energy can be traced back for centuries in a rudimentary form; but it was not until the middle of last century that the principle was given a scientifically practical formulation, more or less simultaneously, by four or six students between whom there was no connection whatever. We may probably assert that even if Julius Robert Mayer, James Prescott Jule, Ludwig August Colding, and Hermann von Helmholtz had not been living at that time, the principle of the preservation of energy would, nevertheless, have been discovered only a little later. I would even venture to assert much the same of the origin of the modern theory of relativity or the quantum theory, were I not reluctant to face the obvious rejoinder that such prophecies after the event are somewhat cheap. I consider the inevitable element of such a process to consist in the fact that with the spread of experimentation and the improvement in methods of measurement, theoretical investigation has been forced in a certain direction almost automatically.

Yet there could be no greater mistake than to assume that the laws governing the growth and effect of scientific ideas can ever be reduced to an exact formula valid for the future. Ultimate any new idea is the work of its author's imagination, and to this extent progress is tied to the irrational element at some point even in mathematics, the most exact of the sciences; for irrationality is a necessary component in the make-up of every intellect.

If we bear in mind that any given idea is due to a given experience, we shall find it natural that the present time, so rich in numbers of new events, has proved a fruitful soil for the production and promulgation of new ideas. If, further, we consider that whenever an idea is formulated, a relation is established between two different events, we shall find, even by the formal rules of combinations, that the number of possible ideas exceeds by one order of magnitude the number of available events.

Another circumstances explaining the vast output of scientific ideas at the present days possibly consists in the fact that owing to the spread of unemployment there are many lively intellects which experience a desire for productive work, and welcome a preoccupation with general theoretical and philosophical problems as a cheap and satisfactory escape from the emptiness of their everyday existence. Valuable results, unfortunately, are rare exceptions. I do not exaggerate when I say that hardly a week passes in which I do not receive one or more papers of varying length from members of every professions-teachers, civil servant, writers, lawyers, doctors, engineers, architects-with a request for my opinion. A thorough examination of these would take up all and more than all of my spare time.

This communications can be divided into two classes. The first is entirely naive and their authors have never considered that a new scientific idea to be valuable must be based on certain facts, so that specialized knowledge is essential for their formulation. The author of these contributions, on the other hand, imagine that they have a fine prophetic gift enabling them to guess the truth direct, never suspecting that every important discovery is preceded by a period of hard individual work. These people, on the other hand, imagine that a happy fate has allowed the desired fruit to drop into their lap in the way in which Newton, sitting under the apple tree received the idea of universal gravitation. What is worse is, that these visionaries float above the surface, never penetrating to the depths, and are too ignorant scientifically to be capable of seeing their error. The dangers which flow from them should not be underestimated. It is satisfactory to note that modern youth shows a growing interest in general questions and in the acquisitions of a satisfactory view of life; but for this very reason it should never be forgotten that such a view is baseless and doomed to sudden destruction unless it has a firm foundation in reality. Anyone desirous of obtaining a scientific view of the world must first acquire a knowledge of the facts. To-day the individual student can no longer form a comprehensive view of every department of science and in most instances he must take his facts at second-hand. It is all the more important that he should be master of one trade and have an independent judgement on his own subject. Personally, as a member of the philosophical faculty, I have always asked that candidate for the philosophical doctorate should give evidence of special knowledge in one given special science. Whether this department belongs to the natural sciences or to the intellectual sciences is not important: What is important is that the candidate should have acquired by actual study an idea of scientific method.

It is generally easy to demonstrate the worthlessness of the type of papers just mentioned; but there is another class which requires much more serious attention because the authors are careful students turning out excellent work in their special field. The scale of scientific work being such as it is to-day, specialization continually becomes more intense and consequently the more serious student experiences a desire to look beyond the limits of his own subjects and to apply knowledge acquired to other departments of science. There is thus a tendency to link too distinct departments by one idea which seems convincing to the student, who in this way transfers the law and methods with which is he has grown familiar within his own sphere to an alien one whose problems he thus tries to solve. There is especially among mathematicians, physicists and chemists, a tendency to employ their own exact methods in order to throw light on biological, psychological and sociological questions. Yet it must not be forgotten that such a new intellectual bridge to be sound requires both its pillars to be securely founded: it cannot fulfil its purpose unless the future pillar, too, has a proper foundation. In other words it does not suffice for an ingenious student to be thoroughly acquainted with his original subject; if his more widely ranging ideas are to be fruitful, he must also have some knowledge of the facts and the problems of the other sphere to which he is applying his idea. This deserves all the more emphasis because every expert tends to exaggerate the importance of his special field in proportion to the length of time spent on it and to the difficulties encountered. And once he has discovered the solution of a problem, he tends to exaggerate its scope and to apply the solution to cases of a totally different nature. Those who feel the desire to take up a higher standpoint than that which their own restricted field allows them, should never forget that there are students at work in other departments of science who are working with equal care and under equal difficulties although with different methods. The history of every science shows how frequently this rule is disregarded. In selecting my examples however, I shall take care to confine myself to physics in order to avoid the mistake I have just been criticising.

Among the more general ideas of physics there is particularly none which has not been transferred with more or less skill to some other sphere by means of some association of ideas, an association depending frequently enough merely upon such contingent external as terminology. Thus the term ‘energy’ leads students to apply the physical concept of energy and with it the physical proposition enunciating the preservation of energy to psychology, and serious attempts of human happiness to certain mathematically formulated laws. The same must be said of attempts to apply the principle of relativity outside physics, i.e., in aesthetics, or even in ethics. Yet there could be nothing more misleading then the meaningless statement that everything is relative. The proposition does not apply even to physics. All the so-called universal contents—the mass or the charge of an electron or a proton, or Planck's quantum—are absolute magnitude: these are fixed and unchangeable components of which the structure of atomism is built up. Of course a magnitude which once was considered absolute has often been found to be relative later; but whenever this happened another and more fundamental absolute magnitude was substituted. Unless we assume the existence of absolute magnitude no concept can be defined and no theory can be formed.

The second principle of thermodynamics, the principle of the increase of entropy, has frequently being applied outside physics. For example, attempts have been made to apply the principle that all physical events develop in one sense only to biological evolution, a singularly unhappy attempt so long as the term evolution is associated with the idea of progress, perfection, or improvement. The principle of entropy is such that it can only deal with probabilities and all that it really says is that a state, improbable in itself, is followed on an average by a more probable state. Biologically interpreted, this principle points towards degeneration rather than improvement: the chaotic, the ordinary, and the common is always more probable than the harmonious, the excellent, or the rare.

Besides the misleading ideas which we have been considering, there is another class which consists of those ideas which, looked at carefully, are seen to have no meaning at all. These play a fairly important part in physics too. A comparison between the movement of an electron around a proton and the movement of a planet around the sun has caused investigators to study the velocity of electrons, although later investigation showed that it is completely impossible to answer these two questions simultaneously. Once again we see the danger of applying ideas and propositions which have provided their value in one department of science to another, and we perceive how great is the need of care in testing and formulating a new idea.

Organizational News

Uttar Pradesh

A discussion was conducted on 25 April, 2014, Friday, at Fatima School, Tajopur in Mau District of UP. The introduction about the Breakthrough Science Society was provided to the students by the College Lecturer Mr. Keshav Singh Yadav (Physics Deptt). It was a one-day long program divided in two parts. The first part was for a discussion, as the topic was "Science and Scientific Outlook". It was conducted by the State Convenor of the Science Society, Mr. Jai Prakash Maurya. The second part was comprised of experimental demonstrations in science and it was conducted by Mr. Shailesh Rao, a state level organiser and Secretary of the Lucknow District Chapter of the organisation. Around 150 students participated in the program. Dr. Tribhuvan Nath Sharma, a medical practitioner also spoke on the occasion.

The Principal of the College, Sister Appolian Pinto, addressed the gathering, and expressed that this type of Science programmes are necessary for the development of scientific bent of mind among the students and among the common people.

Bihar

17 Feb 2014: The Patna Chapter of *Breakthrough Science Society* organized a programme commemorating the martyrdom of Giordano Bruno, at the Muslim High School. Speakers in the occasion were Prof. M.M.R. Akhtar of the Science College, Mr. Tabish Hashmi and Mr. Manoj Kumar Gupta of the Muslim High School, and Mr. Suryakar Jitendra, BSS organizer. Prof. Devendra Prasad of the Patna University presided over the programme.

View of the dais of the Giordano Bruno commemoration programme at Patna, Bihar.

Tamil Nadu

19th Feb, 2014: BSS Madurai Chapter organized a talk on the ocassion of the memorial day of science martyr Giordano Bruno at Sethupathi School, Madurai. Shri Yogarajan, Senior Lecturer, VSVN Polytechnic, Viruthunagar, discussed about the history of science and the role of great minds like Bruno in the renaissance movement. Apart from students of Sethupathi school, students from nearby schools also participated.

9th and 20th May, 2014: BSS Madurai Chapter organised Science Demo programs

The participants of the Nature Study at the Santragachhi Jheel, West Bengal.

in Sellur and Simmakal localities. The science experiments were conducted by BSS activists Ms.Ranjani and Ms.Selvi. Through simple experiments they explained some of the basic laws of science. A good number of children partcipated in the program and raised many interesting questions. At the end of the session a local unit of BSS consisting of 5 members was formed.

The Chennai chapter organised skywatch programs in the third week of May in Vysarpadi and Korukkupet localities. Dr. Venkatesan conducted the program. Youngsters who participated in the program were very curious about knowing various astronomocal phenomena and asked several questions. These were answered in the discussion session that followed.

West Bengal

0n 23rd February, 2014 BSS organized a Nature Study Camp at Santragachi Jheel (lake), Howrah. The attraction of the jheel was the several species of migratory birds from different corners of the world. As always, with the onset of winter these birds started to throng the jheel. But it is unfortunate that in recent times due to the utter negligence of the rail department as well as the Government, the jheel is being continuously polluted and also reduced due to the forceful occupation of a large section of the jheel. The outcome of this is very grave. According to the local people thousands of birds from different species had stopped visiting the jheel and the problem is becoming acute day by day. Visiting the jheel, BSS has raised its voice and has demanded for appropriate maintenance of the jheel and at the same time urged the nature loving people to build up movement to save environment and society.

On 5th June, 2014 on the occasion of 'World Environment Day', BSS organized several discussions as well as demonstrative programmes throughout the state. Centrally a Mass meeting was held in Kolkata. In front of Presidency University a dias was erected and students, teachers and science loving people attended the programme. Dr. Mridul Das Presided the meeting. Dr. Safique-Ul-Alam, Vice-President, BSS spoke on the topic "Food scarcity and pollution."

Organizational News

People's Science Fest in Bangalore

Bangalore District unit is organising a 3-day State-level People's Science Fest at KLE's S.Nijalingappa College, Rajajinagar on 25-27 July, 2014. The fest commemorates the 900th birth anniversary of the great Indian mathematician and astronomer, Bhaskara II, who was incidentally born in Bijapura. Padma Bhushan Prof. U. R. Rao (Former Chairman, ISRO and Space Commission, Govt of India) will inaugurate the fest.
The fest will have 100 Models, out of which 30 are exclusively from BSS. Apart from low cost science models from BSS, there will be models and science shows from premier R&D institutes like ISRO, RRI, IIA, NDRI, JN planetarium, etc., as well as models from medical and engineering establishments on display, including a mobile planetarium. The fest also includes panel discussions and expert talks on important, socially relevant science topics, chart and quotation exhibition on the life and work of scientists.
All are welcome to attend this unique event.

Haryana

The birth anniversary of the legendary scientist Charles Darwin was celebrated at the Divine Dale International School, Pataudi, on 12 February. Mr. Harish Kumar, organizer of BSS, was the main speaker.

Jharkhand

28 Feb 2014: On the occasion of National Science Day, the Einstein Science Club of Ghatsila organized a seminar on the topic "History of Science." Patit Pawan Kuila was the main speaker. Yudhisthir Kumhar, Jay Mahato and Adil Khan also spoke on this topic. Around 120 students participated in this programme.

Karnataka

Bangalore, 15th Feb 2014

BSS Bangalore unit had conducted a study a class on Energy Crisis in India, at Raman Research Institute. The topic was presented by Nandish (Bangalore Executive Committee member) and Rajani K S (Bangalore District President), around 20 science activists had attended the study class. The study class covered a wide area on the current energy crisis in India, the sources of power generation, future plans and trends proposed by the Govt. and political parties versus integrated power policy were discussed. Real and practically approachable solutions were proposed, discussed and debated, which gave a broader scenario of solving the energy crisis in India today and in the future.

Mysore, 22nd and 23rd Feb 2014

BSS Mysore unit organised a 2-day workshop in Taralabalu Vidhya Samsthe in TK layout Mysore. Students and science activists from JSS college, Yuvraja college, Maharani College and Pooja Bhagavat Mahajana College attended the workshop.

Day 1: The 1st session was conducted by Mr. Satish (Karanataka State Convenor) on what is scientific thinking and scientific temperament, need for scientific thinking, and an example to show how scientific thinking helps to find a fast and efficient solution for a social problem.

The 2nd session was a hands-on workshop by Dr. C. V. Nagaraj (Retd. Senior chemist at AGMARK Labs) on detection of adultration in food. Dr. C.V.Nagaraj not only showed how to find adulterants in food but also inspired all the students to take it as a serious issue and to create an awareness among general public on food adulteration.

Day 2: Mr. Chandresh (Bangalore Executive Committee Member) and Ms. Rajani (Bangalore District President) showed how to make science models by using easily available "no cost-low cost" materials.

Mysore, Feb 28th 2014

BSS Mysore commemorated the National Science Day in a village at Hunasoor taluk in Mysore. Ms. Rajani KS (Bangalore District President) and Chandresh (Bangalore District Executive committee member) conducted a miracle busting show and simple science experiments.

Mysore, 1st March 2014

BSS Mysore unit organised a study class in Dr. De. Javaregowda park in Saraswathipuram, Mysore. The study class was conducted by Mr. Satish K.G. (Karnataka State Convener) on "Power Crisis in India — the way forward." It was about the proper understanding of the crisis and comparison of various alternatives such as nuclear, solar and wind to identify the way forward (needs, demand and supply). It also dealt with the skewed policy of pursuing the nuclear way even though it cannot meet the growing power need.

Hassan, 30th April 2014

'Einstein Day' was organised at Malnad College of Engineering, Hassan by the Science Association, MCE. Mr. Saad Siddiqui (BSS member and 6th sem student) took particular initiative. Mr. G. Satish Kumar (State Convener, BSS) in his guest lecture dealt with life-struggle of Albert Einstein.

A chart exhibition on the life and works of Einstein was displayed at the venue.

Bangalore rural, May 1st 2014

BSS Bangalore unit organized a summer camp in the Maralakunte Village. Around 25-30 students from 2nd std to 10th std were in the summer camp. BSS executive Members Chandresh and Nandish from Bangalore unit jointly conducted a whole day session on physics experiments, maths models, and astronomy.

Chitradurga, May 10th 2014

BSS Chitradurga Unit organised a lecture and discussion on "Louis Pasteur's Life and Achievements" in Chitradurga Science College, along with IQAC. Ms. Rajani K.S. (Bangalore District President) presided over the event and gave the talk on Louis Pasteur. She also covered very important aspects from life and struggle of the great legend who contributed to the field of medicine.

Along with it, an organizational structure was given to the Chitradurga District Unit.

Gulbarga, 15th and 16th MAY 2014

BSS Gulbarga unit organised a study class on the need for science movement and the necessity of an ideologically committed organisation to lead the movement. Ms. Rajani KS (Bangalore District President) addressed the students and members from Gulbarga unit. On the 2nd day there was a thorough discussion and meeting for building up of a new organisation in the district.