ISRO-IISc (STC) SP-1

SEMINAR ON

300 YEARS OF NEWTON'S PRINCIPIA

Proceedings of a seminar held at the

Indian Institute of Science, Bangalore

25 September 1986

Sponsored by

ISRO-IISc Space Technology Cell
Indian Rocket Society
Indian Physics Association
Indian Association for Relativity and Gravity
The Centre for History and Philosophy of Science

Organisers and Editors of the Proceedings

Shashi Kant Shrivastava
N. Mukunda

ISRO-IISc SPACE TECHNOLOGY CELL
INDIAN INSTITUTE OF SCIENCE
Bangalore 560012, India

Keynote Address

E.C.G. Sudarshan
The Institute of Mathematical Sciences,
Madras

Newton is perhaps the most luminous figure in all of science. His position is somewhat like that of Adi Shankara in the context of spiritual knowledge, though Shankara was many centuries earlier than Newton. In both cases we are struck by the fact that it would be very difficult to decide who is the next. The scope of Newton's investigations, the lasting nature of his contribution, the wide canvas of his interest and the fact that he survives unblemished even to this day, seems to be something that is a continuing mystery. How could one human being, in a reasonably short lifetime, accomplish so much? Newton systematized much of what was known, invented new methods by means of which these problems could be investigated further and finally wrote it out, all with deliberate forethought; not in many articles to scientific journals, but in one magnificent book, followed by another one, followed by another one and then by another one. So much so, it is very difficult for us, looking back over the gulf of time, to decide what is it that Newton did not do or to realise that there was much that was known before Newton. In fact it is the degree of efficiency of a person, in his presentation and in the perfection of the communication apparatus that one is never able to say who was before him and wonder how was it that it was not well known before him.

Sir Isaac was born in a small village and he was born after his father was no more. His father was neither a scientist nor a government official, but was, in fact, an honest farmer. Apparently he was a reasonably well to do farmer, because Newton was never employed productively until he became famous; after that of course he "minted money". He grew up as a lonely and aloof child and it must have set him apart from his contemporaries and encouraged him to observe the world around him. One of the apocryphal stories say that Newton did keep company with a young lady, but while they were sitting under the tree watching the sunset, he absent mindedly used her finger to clean the bowl of his pipe; apparently after that they were not on very good terms.

It must have shown great forethought on his part, to ensure that his scientific work was not interrupted. Newton grew up in an England which was very much its own master both politically and economically. It was deeply involved at that particular time with experimenting with the democratic system, experimenting with different political philosophies and concerned with philosophic doctrines. Being in touch with the culture of the European continent

at this time, it appears that many people were deeply concerned about which perspective of philosophy was better: an analytic philosophy, which dealt with known facts and analysed them, and tried to deduce from them, what were the principles or a synthetic philosophy, in which you made use of general principles, looked at various facts and made theories, which were more or less dealing with the totality of things. Apparently, from Newton's own views as represented by other people, it appears that he thought that the mathematical approach to nature was in fact part of the analytic philosophy. Newton's view was that natural philosophy analysed phenomena, and mathematical development was simply a clearer way of analysing one's experience of the world. It does happen even today that good theoretical physics seems to be an adventure in ideas of one's own and enlarging one's experience, seeing one's experience held as if in front of you in terms of symbols and their activities and that the computations that are involved which go beyond this analysis are in fact the finishing touches to an otherwise well defined system. Newton believed that the mathematical method he developed and espoused was part of the analytic method.

Newton's times were exciting times in science. Galileo had challenged successfully the existing ideas about physical theories, and orthodoxy was over thrown in favour of experimentation. Not only were terrestrial objects experimented on but the heavenly bodies were no longer so heavenly that you could not measure them and not so celestial that you could not try to find out that they too had to obey laws. Copernicus had both dethroned the earth from its unique position and at the same time elevated the earth to being a celestial body by saying that the earth is *not* the centre of the world: that life was much simpler if you thought of the sun as the centre and therefore the earth to be no less celestial than any of the other bodies. So in a certain sense physics "took off". It became other worldly (and as Dr. U.R. Rao said the ISRO owes a great deal to Sir Isaac Newton). Age old dogmas were subjected to experiment and "pratyaksha", direct experimentation, was considered a more valid method than appealing to general philosophic principles. It is therefore much to Newton's greatness that he combined this new interest in nature, of directly dealing with nature, of directly experimenting on the physical world, but then saw the results in the perspective of a *mathematical* theory. The later British (and by imitation, Indian) predilection to do experiments, draw a curve through the experimental points, plot a graph and leave it at that: and leaving it for somebody in the mathematics department to find out why these curves were of the form they had was not born. In other words the idea that experiment and theory were both essential: that physics was not complete once you had only completed the measurements but that in fact, you had to analyse the measurements through and through using the best methods that you had available. It was to further such ideas and produce such a system that Newton wrote the Princi-

pia. About three fourths of the Principia were almost pure mathematics. Yet Newton had the courage to say that this was a book on the principles of natural philosophy !

Remember that this is not only with regard to mechanics and the motion of celestial bodies, changes of configuration, but also stresses and strains and trying to find relations between them (Legend has it that Hooke caused much stress). So in a certain sense things which were previously statements of sentiment, of loose amorphous experience were now being subjected to direct manipulation, direct measurement, analysis and interrelationship: and finally the concerned physical process was seen to obey the law. So it was a conquest of nature in the sense of consolidation of establishing the rule of the law. As we all know, the rule of the law is a fairly difficult thing to establish even, in our peaceful country.

The times were ripe for new conceptual developments. Newton invented the calculus, but independent of Newton, Liebnitz also did the same. Perhaps earlier, perhaps later, perhaps not quite the same; but nevertheless, two entirely different people, with entirely different background seem to have made the same magnificent discovery. Therefore, the times must have had something to do with it. It seems to me, that both Liebnitz and Newton must have been stimulated by the social and cultural currents around them and recognised that the time had come to deal with processes in themselves; fluxions, flows, rates of change - as parts of the external world. This is a new world view - that the world was not simply consisting of objects which were piled on top of each other, but that processes were an essential part. The mathematics therefore had to move from arithmetic, which was the mathematics of a simple minded capitalistic aggregation of material wealth to a mathematics which was appropriate for a universe consisting of processes. And therefore the mathematics that was invented realised continuous changes in terms of new mathematical entities and new mathematical operations. I do remember the time when I first read a book on calculus. It was mind blowing. Because it seemed for the first time to relate to one's direct experience of rates of change.

It was a time for gentlemen physicists, people who were independently wealthy or who earned a living by other highly paid skills did science for personal satisfaction that there was an innate satisfaction in doing physics: people did not say "Oh! But your degree happens not to be in physics how could you possibly register for a Ph.D.?" It does not appear that people got government grants at that particular time for research. It also appears that at that particular time that there was considerable amount of genuine involvement of intellectuals in science. The discovery and the experiments - findings of physicists were things which were discussed,

studied, criticized, appreciated and assessed by the intellectual elite. Poets did not feel that poetry was really aesthetic and therefore should be against "barbarian science". Science itself was considered as part of development. Newton's discoveries in optics, in particular, caught the poets imagination and people wrote many poems and talked about the symbol of light and light itself having a richness which was there and yet was hidden, light itself could hide what was inside the light. Find it difficult to pass this point without pointing out that at this particular time we may have gentlemen in physics but certainly most of them do science not for personal enjoyment but as a job. Social pressure dictates that it is necessary that a scientist should publish often because otherwise people would say "Last year you did all these things, the last ten years you did all these things, but what have you done recently?".

Newton was a beneficiary of the system in more ways than one, not only was he able to pursue his researches without having to bother about making a living but in later life, as his discoveries were announced, more and more honours and patronage came to him. He was probably one of the most honoured scientists in all of history and perhaps the greatest one.

Newton's optics which came a few years afterwards was more directly accessible to people and in some sense contained new discoveries. Despite the fact that it was so, and poets made full use of it, the very heavy Principia was the one that caught the popular imagination at that time. And perhaps this suggests that despite the many primitive conditions of society at that particular time there was enough good sense to recognize science as a humanistic endeavour. It is remarkable that such a book, which even today one finds difficult to understand was so very popular. During my first two years in college I studied in a small college in Kerala which had a very good library and the Principia was one of the books that was there. And they were heavy, fairly well bound, totally untouched by human hands. I made a deal with the librarian that I could take it home for some time. It was fascinating. Not that one understood all of it, but there was promise of great understanding. There were discoveries in what would nowadays be called trigonometry or differential geometry, intermingled with things about the moon and the planets. That one drew ellipses and saw that it is better that the attracting body was not in the center but at one of the foci. Probably the same sentiment must have activated a lot of people at the time when it was published or soon afterwards namely that here was something which, if only you could understand, you would be able to understand the secrets of nature.

Both Prof. N. Mukunda and Dr. U.R. Rao had mentioned that Newton had many interests in many areas including history and theo-

logy. Apparently he considered himself a scholar in history and a researcher in theology. Not only did he learn much of theology but in fact he tried to combine his science with his theology and he tried to prove the existence of God by showing that the planets moved in appropriate circles and so on.

Not much of his writings on theology I have read but it is quite clear that he took it quite seriously. One thing that must be said about the people at that time is that they did not consider that a person who was interested in theology could not be a real scientist and write silly criticisms about him in their literary or social periodicals. Newton's theological views were tolerated and were appreciated without necessarily being accepted.

Sir Isaac Newton was a man who had many reasons to be thankful to the world around him. Nevertheless, from the little that I have read about him in various places, it is clear that he could be a mean and vindictive person. For 25 years he was the President of the Royal Society. He used that office to distinction and to further the ends of whatever was to be done. Anyone who stood in Newton's way and did not pay him enough homage was swept away, if at all possible. It was not always possible. Robert Hooke, apparently refused to be swept away. He after all, was not only interested in gravitation, but also interested in stresses and strains and he caused a great deal of strain and stress. Sir Isaac Newton did not spare Hooke, even though he could not get rid of him and claimed that almost everything that Hooke did, whether it was attributed to Hooke or not, was actually Newton's own discovery. But most of the others who stood in his way in Britain, not necessarily in science, but anyone who did not pay sufficient amount of homage to him was really made to regret that particular fact. Leibnitz could not be swept away because he was not in Britain. But that did not prevent Sir Isaac from trying to wage war with him, and like Lord Rama he believed attacking him from hiding, using the device of one of his disciples, fighting by proxy. And in this one respect he reminds us of many of the scientific leaders of our own country.

Newton was appointed Master of the Mirt by Lord Halifax, partly because Halifax appreciated Newton's work. Perhaps he even knew about the potential for administration that he had: but also because of the fact that Newton lent considerable weight to Halifax's own innovation in monetary policy and in creating money. Obviously both people benefited from this association. Not only was Newton able to mint money but in fact he was able to mint it in such a fashion that it could not be easily duplicated or destroyed. And Lord Halifax obviously had many reasons to be very pleased because money has been a very popular thing ever since.

In Newton we see an extraordinary phenomenon of a great genius who invented the calculus and used it to develop mechanics and astronomy who nevertheless found time to do his own research in optics and to be able to communicate it effectively if in somewhat heavy handed fashion, to his contemporaries.

In him we find the precision that we find in Panini who composed our grammar. We find in him not only the breadth but also the impatience with alternate patterns of thinking that characterize Adi Shankara. He combines, exhibits in himself the deep and personal involvement with nature that we find in Sir C.V. Raman. And in his life and in his exacting administrative and financial procedures we find a reflection of Tagore's austere aristocracy. He was also a product of a vibrant British European scene which on the one hand dealt with considerable expansion of trade and manufacture but also at the same time did not give way to preoccupation with this to the extent of ignoring literature, culture and philosophy. Perhaps we need to know more about Newton's times and the web of influences which produced such a genius and perhaps we also need more gentlemen scientists whose pursuit of science is motivated by their enjoyment; and who pursue that source of enjoyment along with other interests when their intellects so urge. Of course, it presupposes that intellect is necessary for scientists to pursue research into natural phenomena.

Coming back to review Newton's work: Newton made his discoveries; certainly many of his discoveries, well before the time the Principia was written. Many people who were close to him knew that he knew, but he did not let things out. He obviously knew that what he had and what he was doing were very very important and he was sufficiently assured and secure in his knowledge that he could undertake the monumental work. Newton was somewhat secretive and possessive about his scientific discoveries. And, like Albert Einstein two centuries later, despite the multitude of discoveries he had made, he did not want to let go of any little thing, even if it was not clear that it was entirely his.

I have recently had occasion to go through the correspondence that Srinivasa Ramanuja Iyengar had with G.H. Hardy and there again one sees the same assurance of how important the work is, the possessiveness by means of which you do not want to reveal it to other people and the conviction that sooner or later you are going to do it so well that nobody could possibly take it away from you. So in looking at Newton we see the reflections of traits which are very reminiscent of many of the great in our own country.

I have very deliberately tried not to draw any comparisons between Newton and anybody else in the western world because I really don't know what makes them tick. But many of the Indian

savants that I have mentioned, we have a reasonable appreciation of what was the kind of society which created them, against what odds they rose and what were the beneficial things that they had at that particular time. Looking at contemporary scene, I am of course, distressed to find that we would not be able to take too many people from amongst our midst as foils to Newton. There are many of my friends who are responsible for the management and nature of science and for channelling the huge funds that the government is putting at the disposal of science, who say the time for personal greatness is gone. According to them, it is the team that is to survive. I am sure the team that Dr. Rao is leading obviously has been very successful because their vehicles have reached the appropriate places. There are other teams which are doing equally legitimate things. Yet, one suspects that we need not only teams, but Newtons. Newton's fame does not depend upon all of them joining together and minting money, but rather on his individual contribution. There are people in the audience, whom I would like to have mentioned as positive and comparable people, but it would be probably indiscreet and immodest, those whom I mention will feel that everybody knows that, and those whom I don't mention, will probably hold it against me. It is fortunate that we celebrate Sir Isaac Newton's scientific work and I want to remind you that this is the year of celebration of many other scientific geniuses. It is the birth centenary of Srinivasa Ramanujan. It is also the birth centenary of Erwin Schrodinger. Schrodinger was a human being first, a civilized man next and a scientist afterwards; and in his scientific work he did not find barriers and compartments but found the freedom to have his own world view. Let these celebrations enable us to see that there is no substitute for disciplined insightful scientific discovery.