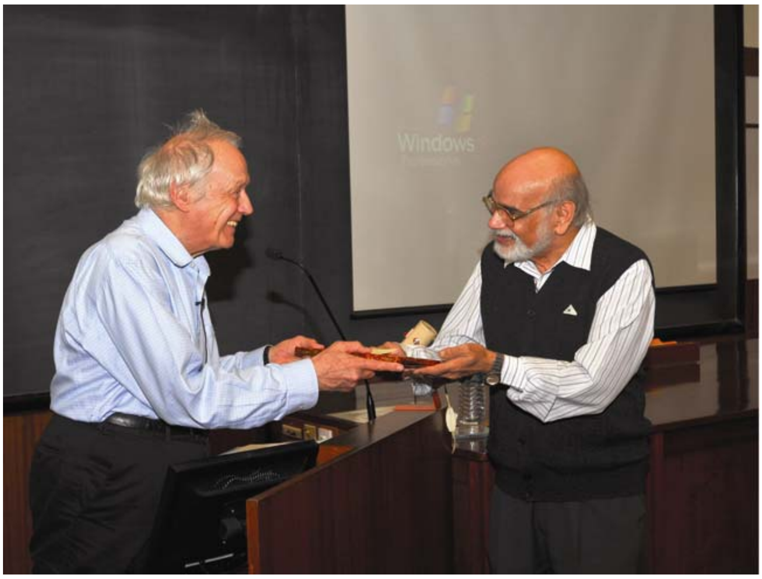
Anthony Leggett – the laws of physics from the atom to our human consciousness

The Nobel Laureate Visiting Programme, a part of the ERUDITE scheme of the Kerala State Higher Education Council, is designed to promote scientific research in various higher education institutions by inviting Nobel-Prize winners to come and spend a few days on campus, interacting with faculty members and students. One such invitation was extended to Prof. Anthony J. Leggett, a 2003 Nobel Laureate in Physics, who visited India during January this year. He delivered lectures, and had informal student interactions at various institutions around the country, including IISERs in Mohali, Pune and Kolkata; TIFR in Mumbai and Hyderabad; IMSc, Chennai; Raman Research Institute (RRI), Bangalore, and CUSAT, Cochin. Leggett spent the last week of his stay at the Mahatma Gandhi University, Kottayam, Kerala.

While listening his public lecture on 'Does the everyday world really obey quantum mechanics?', delivered at RRI on 21 January 2011, I could not help but be utterly fascinated by the firm, solid and sound logic coming from his soft voice, as well as his quite distinct British sense of humour. At the age of 72, Leggett had a densely packed full-day programme, but willingly stole some time to speak to *Current Science*, after which he easily outran me on the stairs, in a hurry for his next meeting.

How did you decide to move from philosophy to physics? Once you did that, how did your knowledge of philosophy help you in your pursuit of understanding the laws of physics?

The story is quite complicated. Basically, I was channelled into the arts and humanities at an early stage, and I ended up doing a degree in Oxford, which involved a fairly substantial philosophy component. The most obvious thing would have been to go ahead and do a Ph D in philosophy, and then get a job in a university. But the more I thought about this prospect, the more I gradually realized I did not want to do this. So I started asking myself, rather self-consciously, why I did not want to go for a career in philosophy. And the more I thought about it, the more it seemed to me that it was because in philosophy, there is no objective touchstone or criterion as to whether what you were doing was good or bad, right or wrong. Everything seemed to depend on the precise turn of phrase, the opinions of your colleagues and so forth. And somehow I felt that I wanted to work in a field which has more objective criteria for right or wrong. I wanted to be able to make non-trivial conjectures about the world and have my experimental colleagues go and find out whether these were right or wrong. So that is the way I finally convinced myself that physics was really the career I wanted to follow. As to the second part of your question, I do not think philosophy has helped me to understand specific pieces of physics better, but it has made me a lot more skeptical than many of my colleagues about things that tend to be taken for granted. Probably, I am a lot more conscious than my colleagues about the very provisional nature of our current scheme of things, and perhaps much more inclined than many of them are, to believe that 200–500 years from now our whole picture of the physical world would be completely different.



Anthony Leggett receiving a token of appreciation after his lecture at the Raman Research Institute, Bangalore.

Do you have a role model, or inspirational figure that you wanted to emulate – like Einstein or Feynman?

I find Feynman to be brilliant, but I do not regard him as a role model. Einstein – perhaps. He was a very, very deep thinker. But in terms of pure physics, the person I think I feel somehow most resonant with is Lev Landau. I have never met him personally, but as a physicist I do relate to him rather strongly. I can follow and sympathize with his line and way of thinking.

What according to you are the most challenging questions in science today?

Well, in physics, I think there are two major issues. One of them has to do with the quantum realization or measurement paradox and the other one – with the questions of the direction of time. I really think we do not understand well either of these problems, and my prediction would be that if there is a major revolution in physics in the next 50–100 years, it is likely to be related to these two issues. If you look at all the major revolutions in the history of physics, they all involve an overthrow of something which up to that point seemed the most obvious common sense. Well, what has not been overthrown yet? The idea that the past and the present can affect the future and not vice versa. More generally of course, there are numerous challenging problems, for example, in the area of neuroscience, which I find absolutely fascinating.

Another important thing is related to methodology in science. Over the last 40–50 years something which we could not have anticipated came on the scene, namely the availability of very large-scale computing. Enormous amount of work these days is done using these computational methods, but will we ever be satisfied with answers to our problems in physics which are purely computational in nature? A typical example would be quantum chromodynamics, where most people working in the area feel that there is little hope of making analytical progress and all one can do is to try to devise more sophisticated computer programs to try to get to some answers. The questions is, even if this is successful will we regard it as a real theory of the world, or will we require the sort of gestalt we have been used to in physics before the invention of computers? I suspect the latter. I think we will never be totally satisfied with a solution, however complete, which is entirely based on numerical computation.

How has science, or the way of doing science changed over the decades of your working experience?

If I go over my own experience with physics, one statistical observation I have is the actual growth of physics literature. If you go back to the year 1900, you could literally read all the papers produced during that year! Then it started to grow and sometime in mid-60s, it suddenly took off. The number of papers published increased by a factor of three, while the number of physicists stayed the same. I personally think there is too much published in physics today. It is becoming increasingly difficult to sieve through physics literature and this process is further facilitated by on-line repositories like Los Alamos, where basically there is no gatekeeper, no criterion.

Another big change is the internationalization of physics. Fifty years ago physics was concentrated in Western Europe and USA, with high quality but small input from India. Essentially nothing was coming out of China, South America and other parts of the world. Today, internet had a great role in lifting people from less technologically advanced countries to an equal plane with Western Europe or America.

Another interesting thing is that when I started to do physics in the early 60s, ideas about, for example, the origin of the world, were regarded as so speculative that it was almost embarrassing to discuss them in public. Now the world has turned completely the other way. Almost everyone seems happy to extrapolate the laws of physics which are only tested in the laboratory or perhaps occasionally in the nearby cosmos, and apply

A. J. Leggett and superfluidity.

Anthony J. Leggett is a prominent physicist in the area of low temperature physics, who was awarded the 2003 Nobel Prize in Physics for his theoretical work on superfluid He-3. He was born and grew up in South London, where during his childhood years one of his favourite activities was to dig holes in the earth. In his autobiography, Leggett shares his suspicion that the peculiarity of this activity might have something to do with his decision to become an explorer (after giving up the idea of becoming a railway signalman). Leggett won a scholarship from Oxford University and moved there for his undergraduate degree in classical subjects. However, sometime before his graduation, he realized that being a philosophy teacher was not his cup of tea and after serious introspection, decided to pursue physics. But doing another undergraduate degree in a different field was, as he says: 'practically unheard of in those times'. The stroke of luck came in the form of *Sputnik* which was propelled to space in 1957 by the Soviet Union to the shock and dismay of the Western world. Suddenly, it was realized that the best brains in the UK are channelled into studying 'useless subjects', rather than science and engineering, and an abundance of scholarships were granted to people from the humanities who wanted to study science. Leggett completed his undergaduate and graduate studies in physics in Oxford and spent a year of his post-doctorate in Japan, where he persistently studied Japanese and purposefully refused to mingle with other foreigners or speak any English. In his autobiography, he shares that some of his Japanese colleagues could not find a more logical explanation to such strange behaviour than the one which involved him being a CIA trainee!

Leggett actively started working on superfluid He-3 during his year as a postdoctorate in UIUC. During the 12 month period between July 1972 and 1973, he developed the theoretical description and formulation for the experimentally observed superfluid He-3 that marked a major step forward in our understanding of superfluidity. It is for this work that 30 years later he was invited to Stockholm to receive the Nobel Prize. Soon after joining UIUC in 1982, Leggett's research interest shifted from superfluid He-3 to high-temperature superconductivity, low-temperature properties of glass and BEC systems. However, his main line of research in the recent years has followed the theory of experiments that aim at predicting whether quantum mechanics will hold true when moving from small atomic-scale systems to everyday macroscopic objects (solving the Schrödinger's cat paradox).

What is superfluidity?

Superfluidity is a quantum mechanical state of matter in which the viscosity and friction of a liquid disappear when cooled down close to absolute zero as a result of its atoms occupying the same quantum state. The nuclei of the more common He-4 are bosons; therefore, they can easily occupy the same quantum state, However, in He-3, whose nuclei are fermions, the atoms first pair up into what are known as Cooper pairs to form bosons in order to turn He-3 into a superfluid. Apart from serving as an experimental evidence for the laws of quantum mechanics, superfluid helium finds its major application as a coolant in MRI imaging systems. Superfluids are also used in very high precision gyroscopes to measure theoretical limits of some gravitational effects.

these to conditions which are orders of magnitude different. Even things like Hawking radiation, which is a brilliant piece of mathematical analysis, require that the standard quantum mechanics continues to work, in the way we know and love, under the extremely anomalous conditions near a black hole. But how do we know that? We do not. I personally think one should be a bit more cautious – the pendulum has rolled too far in the opposite direction. Particularly when one talks about things like quantum cosmology.

How do you foresee the future of quantum mechanics?

I think it is quite interesting and not only for elementary quantum mechanics as part of solid state physics which has already had large technological spin-offs, but also for more sophisticated ideas like entanglement and quantum information which are also becoming quite important at a practical level. People have already used quantum cryptography to effect bank transfers and I think that this is a very real and exciting possibility. At present, we do not know where quantum computing is going. I personally suspect that in order for quantum computing to really take-off and become some kind of reality, we have to go way beyond its currently known applications. The currently known applications are related to factoring very large numbers, which of course is very useful in cryptography, but I think it will have a decreasing importance. So if we are to make sure that this field does not wither and die, I think it is necessary that we are much more imaginative and come up with ways to make quantum computers do qualitatively different things than what we know today.

A major focus in theoretical physics today is the search of a theory of everything with string theory cited as the most promising candidate. Do you think we should search for such a theory and if we find it how do you think science would change, if at all?

Well, in some way our curiosity has got to force us to try and unify this rather messy situation which exists in particle physics and cosmology in something which we call 'the theory of everything'. But I do not think of it as particularly fundamental. Almost by definition, when we talk about macroscopic matter, we can actually do real experiments. Whereas right now, it is extremely difficult to do any experiments which are relevant to the basic arguments of string theory. I have absolutely no objection to people spending their time on it, but it is not something that I have personally ever felt drawn to. I would much rather make unexpected and interesting predictions about the behaviour of macroscopic matter and excite people to test those experimentally.

Do you think science is becoming the religion of the next generation?

Yes and no. People do put absolute faith in science or certain areas of science, which is comparable to what in the past they put in varieties of religion. On the other hand, I think there is a difference. The world today is somewhat operating within the same paradigm, and we roughly agree on the kinds of questions that are sensible to ask, the kinds of evidence you ought to supply and so forth. Most of us worldwide also agree on what constitutes scientific fraud and what does not. I think we somewhat have a more common basis and I find it a little difficult to believe that real-life wars will be fought over the interpretation of quantum mechanics, for example.

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