

An Interview with Ashoke Sen

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Ashoke Sen was born in Calcutta and studied physics at the Presidency College of the city, at the Indian Institute of Technology in Kanpur, and did his doctorate at Stony Brook. **He has been with the Harish-Chandra Research Institute for the last seventeen years.** His main area of work is String Theory, which has deep connections with mathematics. Ashoke Sen is a **Fellow of the Royal Society** in London, and he has won many prizes and awards, such as the **Infosys Prize in the Mathematical Sciences for the year 2009**. Recently, he was among the first recipients of the Fundamental Physics Prize “for opening the path to the realisation that all string theories are different limits of the same underlying theory”. This richly endowed prize has been set up by the Russian billionaire Yuri Milner for rewarding scientific breakthroughs. Ashoke Sen was the only recipient from Asia of this inaugural prize; the others being Nima Arkani-Hamed, Alan Guth, Alexei Kitaev, Maxim Kontsevich, Andrei Linde, Juan Maldacena, Nathan Seiberg and Edward Witten. *Chandan Singh Dalawat* recently had an interview with Ashoke Sen at Harish-Chandra Research Institute.

Chandan Singh Dalawat: Congratulations on receiving the Fundamental Physics Prize. It must be very gratifying to see so many years’ hard work so richly rewarded. You went to school in Calcutta, then to Presidency College (founded by the British colonial authorities) for your undergraduate studies and to the Indian Institute of Technology in Kanpur for your master’s degree. What role have these institutions played in your formation, and when did you first realise that you could become a physicist?

Ashoke Sen: Of course the institutions had a major role in my formation but it is hard to quantify it. For example, if instead of these institutions I had attended some completely different sets of institutions, would I be very different? I do not know.

I wanted to be a scientist since my childhood, but had no idea of what science meant. This desire remained with me, and as I went to college and then to IIT I slowly learned what science means.

CSD: What are your impressions of the state of science education in India at the school level and at the university level? Do you feel that there is some room for improvement in the number of institutions and in the quality of teaching?

AS: Since I am not involved in school and university level science education, it is hard for me to comment on this. There is always room for improvement in any system, but to really identify what they are one needs to be involved in the system which I have not been.

CSD: I was quite disappointed a few years ago by the quality of the standard mathematics textbooks in our high schools. Have you seen the science textbooks in use in our high schools and colleges, and what do you think of them?

AS: I have seen some textbooks. All I can say is that they are better than what we studied in school.

CSD: The Indian government has recently created a number of new science institutes devoted to teaching and research. I'm told that they are finding it difficult to hire the right people. Were you involved in their creation, and are you somehow involved in their functioning? How does one explain their inability to find the right candidates, and what are the prospects of these institutes?

AS: No I was not involved in any way in their creation or functioning. It is not surprising that they are finding it hard to hire people. If one suddenly creates a large number of institutes like this, the demand for good people suddenly goes up, and there are simply not enough people available to fill these positions. But the situation will probably improve over the next 10–15 years as larger number of trained people become available.

CSD: Some Western universities have put many of their courses online for free, while others make them available for a fee. Do you think these online courses might help improve the quality of science education in our universities, and should we do something similar to make up for the scarcity of good teachers?

AS: Yes one should certainly try to make use of these as much as possible. These cannot replace classroom teaching completely, but one may be able to work out an effective system by combining these online courses with classroom teaching.

CSD: Let us turn to the quality of scientific research in India. Do you think that we have largely achieved our potential, or do we still have some way to go?

AS: There is certainly a long way to go. It is hard for me to comment on all areas of research, but I feel quite positive about my area of research i.e. string theory. India now has a large number of excellent people working in various institutions, and I see a very bright future.

CSD: There are many attempts at quantifying or measuring the scientific achievements of individual scientists. A crude measure is the number of publications. These “metrics” seem to influence decisions about hiring, promotions, awards, grants, and other fellowships. In your

experience, do these metrics reflect quality, or has their influence been largely negative?

AS: One certainly has to be careful about using these metrics. But I certainly see a positive point: by providing us with some quantitative measure, however defective it may be, it prevents people from blatantly misusing their power to promote incompetent people, and more importantly, from preventing competent people for rising up. Now if somebody is pushing for someone with few publications or citations, at least a third person can ask for a justification. In genuine cases it should be possible to provide such justification. Similarly if someone with large number of highly cited papers is being denied a grant/award, at least the granting authority can be asked to provide a justification for their action. Again in genuine cases it should be possible to provide such justification.

CSD: You have travelled all around the world, and you have seen how science is organised and managed in other countries. Do you think that they have something to learn from the way science is run in India? Or, perhaps, do we have something to learn from them?

AS: In theoretical physics the needs are few, and as long as we have a computer and an internet connection, and some money to travel to conferences and invite visitors, we can do our work. So the research is largely unaffected by how the administration functions, and in this sense I think there is not much difference between how the groups function abroad and in India. In experimental sciences things are certainly more complex, but I am not competent to comment on that.

CSD: We both work at the Harish-Chandra Institute which is devoted to research and where teaching takes place only at the graduate level. Such research institutes are almost the only places in the country which run decent graduate programmes in mathematics and theoretical physics. Do you think it is possible to revivify the graduate programmes in the various universities in the country?

AS: There are some excellent people in the universities who have produced excellent students. Their number may be few, but their existence certainly shows that it should be possible to make the universities vibrant centres of research by providing them with sufficient resources, and simplifying the bureaucracy. This in turn will attract bright people to join universities.

CSD: Every week we get emails soliciting papers for journals such as Fuzzy Sets, Rough Sets and Multivalued Operations and Applications (I haven't made that up). How do you explain the proliferation of such journals, and do you think they pose a threat to genuine scientific research?

AS: I just delete these mails, and I presume many of my colleagues do so too. So as far as I can see, the problem they pose is the time that one wastes in deleting these mails.

CSD: At least in mathematics, it is very important to have access to old papers. The European Digital Mathematics Library has taken the initiative of digitising old journals and to make them freely available online. However, old issues of many other journals are accessible online only to those who can afford to pay a hefty fee. Do you think that fundamental research, completely devoid of military or commercial interests, should be shared freely and widely?

AS: Yes I certainly think so.

CSD: The Cambridge mathematician Tim Gowers has recently called on the scientific community to boycott the journal publisher Elsevier for its policies regarding pricing and access. Our own library has to make very tough decisions about which journals to prune from the list of subscriptions. There was massive support for the boycott, even among some Elsevier editors. Do you think that the responsibility for making their work more widely available lies with the scientists?

AS: For papers written after early 1990's I never consult the journal but instead look at the arXiv. So to me the cost and availability of the new journals seem irrelevant for one's research. As long as we can work out a scheme for accessing the pre 1990's journals, we can get rid of the problem we are facing with Elsevier and any other expensive journals of that kind. (In any case I have not published in an Elsevier journal for many years, probably for about last 15 years.)

CSD: You use a lot of mathematics in your work, and the level of mathematics being used in string theory is far higher than in any previous physical theory. In return, string theory has been inspiring some purely mathematical insights, especially in algebraic geometry. The fact that physicists can predict some mathematical results with uncanny accuracy perhaps points to some underlying mathematical principles which have not yet been enunciated. Instead of asking a direct question, I would like to hear your view of the relationship between mathematics and string theory (and its generalisations).

AS: I do not really have any great insight into this. The inability to produce the kind of energy that is required to verify string theory by direct experiments compels us to look for other ways to convince ourselves that string theory is on the right track. One of these ways is to test the internal consistency of the theory in all possible ways; if the theory passes all such consistency tests then it bolsters our confidence in the theory. It is fortunate that such consistency tests often leads to non-trivial mathematical identities which are often unknown even to the mathematicians.

CSD: In mathematics there are some vast research programmes such as the conjectural theory of motives or the Langlands Programme. Although very sophisticated mathematics is required for their proper formulation, their aims and achievements can still be illustrated through concrete examples. What are some of the fundamental problems of theoretical physics and how would you

illustrate them?

AS: The fundamental goal of string theory is quite clear, it is to find a single theory that explains the origin of all matter and the forces between them. If we ignore the force of gravity, then this can be achieved by quantum field theory. But once we try to include the effect of gravity, the techniques of quantum field theory seem to break down. String theory on the other hand naturally incorporates gravity, and there is strong indication that it can also incorporate all the other forces and the kind of matter we see in nature.

CSD: **Has it sometimes happened to you that you needed some mathematical result for your work but didn't know whether it is true or not, whether it had been proved or not; you look around, and it turns out that precisely that result has been proved by someone many years ago?**

AS: It has happened occasionally and in such cases I seek Surya Ramana's help in finding the mathematical result. But more interesting cases are those in which even after looking around I found that the result was not known to the mathematicians. I shall give two examples. The first one concerns my work on duality in mid 90's — the work that was cited in the prize. I found that the existence of certain symmetries in quantum field theories and string theories leads to a precise conjecture about the cohomology of an infinite class of non-compact manifolds. I verified this for some examples, but for the rest of the manifolds the cohomology was unknown at that time. Later a large part of this conjecture was proved by Grame Segal and Alex Selby. As far as I know the complete proof is still not available.

The second example is much more recent. Based on the study of black holes I arrived at the conjecture that certain infinite subset of Fourier expansion coefficients of a class of Siegel modular forms must be positive. I verified this explicitly for a finite subset of Fourier coefficients and also in certain asymptotic limits, but otherwise had no proof. Very recently this has been proved for a small (but infinite) subset of these coefficients. This was the result of collaboration between a mathematician (Kathrin Bringmann) and a physicist (Sameer Murthy). But again a large part of this conjecture still remains unproven.

CSD: **Some people hold the view that the boundaries between physics and chemistry and biology are somewhat artificial, whereas there is a sharp boundary between mathematics and the natural sciences. This is not to say that they don't influence each other, but the aims and the preoccupations are different: proof, beauty and relevance in mathematics, correspondence with reality and utility in the sciences. What is your view?**

AS: I certainly agree that in physics, experimental test always takes precedence over beauty. However mathematical consistency is a must for all physical laws.

It is universally accepted that the fundamental laws of physics must be written in the language of mathematics, and must be logically consistent to the same extent that a mathematician will demand a system of axioms to be internally consistent. A physicist may be more easily satisfied than a mathematician about such internal consistency, but eventually if some mathematician takes the effort to

prove that a system of axioms is internally inconsistent, then the physicist has no option but to abandon that system — even if that system of axioms may describe correctly the results of available experiments — and look for alternative set of axioms which may describe the laws of nature. From this viewpoint I do not think that the boundary between mathematics and physics is that sharp.

CSD: Are there some mathematical results or theories which you particularly admire, even though they might not have been directly useful to you in your work?

AS: Given my limited knowledge of higher mathematics it is difficult for me to answer this question.

Since this is not the answer you will get from all string theorists, I should perhaps try to explain my position. String theory has a wide spectrum of people, from those who use very little higher mathematics and lots of physical intuition to those who are highly mathematical (and of course there are few who span the whole range). One of the greatest strengths of the subject is that people over the entire spectrum can make nontrivial contribution to the growth of the subject, and in fact one needs contribution from the whole spectrum for the overall growth of the subject. In this spectrum I am somewhere in the middle. I am willing to learn new mathematics if it is needed for my research (particularly if I have more mathematically oriented collaborators who can help) but I do not really have a global picture of mathematics as a subject.

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Chandan Singh Dalawat was born in a small village in the foothills of the Aravallis, and now lives on the banks of the Ganges. He is interested in Number Theory and its history, and enjoys teaching the subject.

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