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Interview with Prof. B.V. Sreekantan, cosmic ray physicist and astronomer. By R. RAMACHANDRAN

THIS IS THE SECOND PART OF A TWO-PART INTERVIEW.

ON July 10, the Tata Institute of Fundamental Research (TIFR) felicitated its former Director, the cosmic ray physicist and astronomer B.V. Sreekantan, to mark his 90th birthday, which was on June 30. Prof. Sreekantan has many achievements to his credit. He was part of the team that first detected atmospheric neutrinos in India, at Kolar Gold Fields.

The planned launch by the Indian Space Research Organisation (ISRO) of Astrosat, a multi-wavelength X-ray astronomy spacecraft, in September, and the proposed India-based Neutrino Observatory (INO) in Theni district of Tamil Nadu are milestones in the programmes that Sreekantan initiated at the TIFR. During his tenure at the TIFR, he put India on the world map of high-energy physics and built up a vibrant school of experimental high-energy cosmic rays.

This is the second part of the interview *Frontline* had with him. The first part was published in the issue dated August 21, 2015. Excerpts:

At the Massachusetts Institute of Technology (MIT), you got associated with X-ray observations from the source Sco X-1 that Bruno Rossi's group was about to begin when you reached MIT…

See, there were only two X-ray sources that had been discovered until then [the sun and Sco X-1, an extrasolar source]. When I went there, the question was the identification of the astrophysical object that was the X-ray source [in the Scorpius constellation]. For identification, you need the coordinates as accurately as possible with repeated measurements. [The Japanese physicist Minoru] Oda was also visiting at that time. He thought of this [technique of] modulation collimator. When I went there, we worked together a lot on how to use this modulation collimator, how to calibrate it, etc. When we tried to calibrate it, we ran into a lot of problems. Unfortunately, right at that time Oda had to go back to Japan. So I pursued it and finally found out how it could be done.

So you became part of the first extrasolar X-ray source Sco X-1 identification experiment…

Yes. Identification of Sco X-1 in a particular star, and that star [V818] was not so important in the visible region but was the strongest X-ray source. So that was the anomaly for a long time. Then pulsars were discovered a few years later and then the source [Sco X-1] turned out to be the centre of that type of pulsar [system].

Were these Sco X-1 emissions soft X-rays or hard X-rays?

This experiment was a rocket experiment, in soft X-rays. [Soft X-rays have low energy below 10 keV and are totally absorbed by the atmosphere. Only rockets and satellites, which reach altitudes of 100 km and more, can detect soft X-rays. Hard X-rays have energies above 10 keV, which can penetrate down to lower altitudes depending on the energy. Balloon-borne experiments, which can go up to 50 km, are used for studies of these.]

But when you came back you started working in the hard X-ray region and began balloon experiments…

See, when I came back, we were not ready with rockets or satellites to do soft X-rays. So I started balloon experiments. In the U.S., too, they had started balloon experiments; George Clark in MIT itself had started. And then we started here. That gave us good results for quite some time.

Was there a balloon production facility already here?

Yes. That you know was independently started by [Homi J.] Bhabha and [M.G.K.] Menon. Menon was essentially the person behind the plastic balloon development. But, unfortunately, what happened was that the balloon fabric that was being used at that time in India was not suitable for night flights. But for my experiment in X-rays, it had to be done at night only; sources are only available at night.

So you had to import the fabric…

At that time we imported. But now we make. Starting with [R.R.] Daniel and [S.V.] Damle, they developed very good material [for X-ray astronomy experiments].

But now apparently the National Scientific Balloon Facility in Hyderabad is not being put to good use at all. Why is this so?

A lot of improvement was done by [R.K.] Manchanda. But, unfortunately, now the interest is lacking. Now, nobody uses balloon flights for astronomy so much.

But you think there could be some interesting experiments that could be done at intermediate heights even today…

With the development of large area detectors and satellites today, it is not so profitable to pursue X-ray and gamma ray astronomy with balloons. But there are other atmospheric experiments [that can be done]. It is being done, but not at a high level. In fact, our people at the TIFR are not doing any work with balloons anymore.

But the facility is still being maintained by the TIFR, is it not?

Yes. The facility is there. A parallel group has been set up for doing atmospheric studies. Balloons are also used by them.

When did your rocket experiments and collaboration with ISRO begin?

After a few years of my coming back, Thumba was ready for rocket experiments. And we started doing soft X-ray experiments with rockets. U.R. Rao [former ISRO Chairman] had also started and both of us were doing experiments for a few years before satellite experiments started. And in the very first satellite [Aryabhata], we had an X-ray experiment. U.R. Rao was in charge of the project. But, unfortunately, the satellite failed because of a power supply problem.

We have today come to the stage of launching a dedicated X-ray astronomy satellite, Astrosat. What are your impressions and views on Astrosat?

Discussion on Astrosat you know started when I was here. It has taken more than 20 years [from the time the idea was mooted]. But still they say it can give some results. Let us hope.

The same is true of the INO also. You started neutrino research in the country…

The INO is in very bad shape. Unfortunately, it has become a political issue.

At the felicitation function, many people spoke about the many initiatives you took after you assumed charge of the directorship of the TIFR, resulting in new avenues of research opening up. As a chief manager of the institute, how did you manage some of the problems you encountered and see these initiatives through? For instance, you have mentioned the initial opposition within the institute to the setting up of the National Centre for Biological Sciences (NCBS) in Bangalore.

See, I had already worked in the institute for 27 years. When Bhabha died in 1966, I was still at MIT. When I came

back, of course, Menon had taken charge. He was expected to become the Director and so there was no problem. And then, you see, the Electronics Commission Report, which Bhabha had signed, had to be implemented. Then [Vikram] Sarabhai said the only person who could maintain continuity was Menon. Though he was not an electronics man, Menon was appointed as the [Department of] Electronics Secretary. He did a marvellous job, and for two years he tried to see if he could continue as the Director of the TIFR. He found that it was impossible. That's when all the faculty members said that I should become the Director. They made a representation to the council, and that is how I was chosen. I did not apply for the post. By then, the institute had matured. [R.] Narasimhan [who pioneered computer science in India], who was quite a senior man, came up with the idea that for both the health of the institute and the health of computer science, we should probably take it out of the TIFR and set it up as a separate centre, and that is what we did with the help of the Department of Electronics. I had known R.V.S. Sitharam right from the first day of my joining the institute. He had developed the SAMEER [Society for Applied Microwave Electronics Engineering and Research]. That also could be established as a separate unit with the help of the Department of Electronics. Since Menon was the Secretary, Electronics, all this became easy for me to implement.

When we were discussing the Seventh Plan [1984-89] and the Ooty Radio Telescope had already been operating for many years and had already got the best results, some members felt that we have to have an alternative programme [in radio astronomy]. [Govind] Swarup [the architect of the Ooty telescope and later the Giant Metrewave Radio Telescope (GMRT)] was not at that time giving thought to that. So I induced him to take this opportunity—when [Satish] Dhawan was there [as Chairman, ISRO] and [Raja] Ramanna was there [as Chairman, Atomic Energy Commission (AEC)] we should be able to get through any major proposal in this direction. Then he came up with the idea of GMRT.

Then one day Obaid [Siddiqi] came and said, "I want to start another biology department, not in Bombay [Mumbai] but somewhere outside, and there I want to do pure molecular biology, molecular processes of life." I asked him whether he wanted to start work in stem cells—just then research on stem cells had started. He said: "No. No. I am not in the least interested in stem cells." That can be done even in a small place.

At that stage, stem cell was a very small part of biology research as far as biologists were concerned; now, of course, it is a very big thing. Then when I went with the proposal to the molecular biology faculty, they all said, "No. We don't want another centre." Something similar had happened with respect to setting up of molecular biology in the TIFR itself. When Bhabha came with the idea of starting molecular biology to discuss with the faculty, except for myself and Narasimhan—Menon kept quiet because he already knew that Bhabha had taken a decision, which we did not know—all the others — [S.S.] Dharmatti [an NMR pioneer], [B.V.] Thosar [nuclear and solid state physicist] and [Devendra] Lal [cosmic ray and nuclear geophysicist]—opposed it. Lal said, "We don't have any books in this area. It is an entirely new field." Phadke said, "Yes. It is a good opportunity to start new work." But was a little bit neutral.

Anyway Bhabha had taken the decision. As I had mentioned at the [felicitation] function, A.V. Hill [an English physiologist] suggested to Bhabha in 1944 itself that he should consider including biology and that it was a neglected area in India, and he had waited for 18 years to find the right man [which was Siddiqi]. So when he came up with this idea, I supported it, and when I took it to the council, J.R.D. Tata jumped, saying we should do it and gave the example of the Max Planck Institute. But Ramanna was a little unhappy because already you know the DAE was under stress as they were already supporting two [biology] institutions: the BARC molecular biology section and the TIFR molecular biology group. "How can we support a third one?"

And at that time the State government in Karnataka had decided not to have any more satellite institutions in Bangalore. They wanted them to be in neighbouring places like Hasan or Tumkur. It became quite a problem because for molecular biology you also need international collaboration and international visitors. You cannot have it in a place that is not accessible, and in that area there are very few places that are accessible by air. Then my brother suggested, why don't we go to a place where they have a lot of land but don't know what to do with it. Then you don't have to go to the government. That is how we went to GKVK [Gandhi Krishi Vignana Kendra, University of

Agricultural Sciences (UAS), Bangalore]. Before that we went to Indore. In Indore, CAT [Centre for Advanced Technology of the DAE] had been started. So Ramanna suggested why don't we go there. But Indore did not suit us. Then we looked at Mysore. There we could not find a proper site, and it was also not very well connected. We also went to Hyderabad. Somehow, finally, it settled at GKVK.

Before this GKVK place materialised, the biology unit occupied some space at the Indian Institute of Science (IISc) along with the TIFR's Applied Mathematics Centre there. How did that arrangement come about?

Oh! That's a different story. What happened was Satish Dhawan was a member of the TIFR Council. When Menon was the Director [Dhawan was the IISc Director], he said he would like to have the benefit of some of the mathematicians of the TIFR spending time at the IISc. So collaboration with the IISc was worked out. The collaboration was actually blessed by J.R.D. Tata and also [Rustum] Choksi. In 1974, just one year before I took charge, they started a joint programme in [applied] mathematics with the IISc. Somehow, from day one this did not work well because this was done at such a high level and not at the departmental level. The mathematicians at the TIFR and at the IISc were not consulted. Later on, it was more or less forced upon them. So right from the beginning it did not go well.

When I became Director, I went to [S.] Ramaseshan, who was the Director of the IISc, and requested him to see if some policy could be worked out by which we could be tolerated there. They were not even prepared to tolerate us on the campus. I somehow managed to get another [Rs.]15 lakh or so from [Homi] Sethna [the then AEC Chairman] for starting a building there. We built a building, and by then the radio astronomy people [in Ooty] wanted computer facilities. So in that new building, radio astronomy was on one side and mathematics on the other. Later on, when GMRT was approved, all the basic work [on it]—design and other things—was done in Bangalore, and after that they left for Poona [Pune]. And that was the time when these [biology] people wanted a place in Bangalore to start their work. Siddiqi's main argument was that there were young biologists [abroad] who were trying to come back. And that is what happened. One by one, four or five people came. They started the work in this building, and later on we got this GKVK. They now have a stem cell centre also there.

Some years after your tenure of directorship, you moved out of the TIFR to the National Institute of Advanced Studies (NIAS) in Bangalore. Were you ever part of the TIFR Council after your directorship?

No. What happened was there was some kind of agitation by members of the staff of the TIFR that retired people from the TIFR should not be on the council. You see, they did not want Menon to continue for a very long time. So they did not want a Director to be on the council after retirement. Menon had retired as Director but continued to be on the council. During my time he was on the council. They did not see the benefit of that. So I never have been on the council except as Director.

Most people consider that when you were the Director, it was the golden period when the TIFR expanded with new activities. But do you have any observations to make on the subsequent periods?

After that nothing new has come up. During Virendra Singh's time [1987-97], everything carried on; projects were already there. The GMRT proposal was approved during my time. Its implementation was during his time. Also, implementation of the NCBS was after I left. I was a member of the panel for laboratories, housing and all that. By then, Virendra Singh had taken over. After that, why it has been like that, I don't know. I left contact with the TIFR during the periods of [S.S.] Jha and Shobo [Bhattacharya]. I really did not keep track of the TIFR.

Even now, the initiative of a new campus in the University of Hyderabad has really not taken off.

Nobody is clear about what they want to do [at the new campus]. In fact, even while discussing with the new Director, it seemed that they still don't know what to do. They got 40 acres of land and some money also but it is not clear… need good experimental people to start activities there.

As a member of the Council of the Indian Institute of Astrophysics (IIA) in Bangalore, did you have a role in its

initiative of setting up the Hanle Telescope in Ladakh? You had chaired the committee that recommended its setting up…

That happened because Ramnath [Cowsik] came back [from the U.S.]. I was on the council and Menon was the Chairman. We induced him with great difficulty—he did not want to come back to India —and, of course, Rad [V. Radhakrishnan, the then Director of Raman Research institute (RRI), Bangalore] helped us. He did a marvellous job. I don't take any credit for that. It was all Ramnath's work. I supported him, but [it was] his initiative and drive in setting up, in fact, setting up the institute on a proper footing.

But there was a lot of internal opposition to the setting up of the Hanle Telescope.

There was no internal opposition as such. Professor [J.C.] Bhattacharya [former IIA Director and IIA Council member then] was all for it. The only thing was some of them, who were solar astronomers, wanted the solar project to be pushed. But they had not made any search for proper sites. Solar astronomy requires a different kind of survey. Ramnath [as Director, IIA] tried to do that. [K.R.] Sivaraman was there, and he had gone around India and tried to find a site for solar astronomy. But he was not very successful. After Hanle was found for optical astronomy work, they later found a suitable site near by there itself. But the only problem there is that we are very close to China. So there is always a hesitation in making big investments there.

Now, of course, the high-energy gamma ray observatory HAGAR/HEGRO has also been set up. Hanle can probably be shaped into a very good astronomy observatory.

Yes. They have done very good work in the last seven-eight years. Lots of papers have been published. [G.C.] Anupama has done very good work.

But despite Ramnath's best efforts, the Kavalur telescope does not seem to have produced really good science in all these years. What are the plans now for Kavalur? Do you have any idea?

Firstly, they have refurbished everything at Kavalur; they have changed the entire system. But, observationally, Kavalur is not a perfect site actually. That is a serious problem. The number of nights you can get for observation is very few.

CONSCIOUSNESS RESEARCH

After moving to the NIAS, you have taken a lot of interest in the philosophy of science; you have also been talking about consciousness and all that. Of course, you have mentioned that you had been interested in these issues right from your younger days. But how did it shape into a proper programme of study and research in the field at the NIAS?

After my directorship, I was at the TIFR for five years with the INSA Ramanujan professorship. And then the question came, what shall I do next. We decided to move to Bangalore. At that time, my two sons were going to the U.S. So I worked out a deal with MIT that I will come there and spend two years working on their satellite. They agreed. I was about to go when my sons were about to leave. Then it just so happened I went to Bangalore on Ramanna's invitation. He asked me what I was going to do. I told him I was going to MIT. Then he said, "No. No. You are not going to MIT. You are going to camp under me and set up this institute in Bangalore and assume some responsibility." That is why I went to the NIAS. Then I asked him, what do you expect me to do? He said, it is up to you. Just then [Roger] Penrose's book *Shadows of the Mind* had come. I studied that. That opened up the possibility that there was scope for physicists to do something in the area of consciousness. So I told him that I would start some work in the area of consciousness research.

My idea was to have some collaboration with NIMHANS [National Institute of Mental Health and Neurosciences, Bangalore]. But when I went there, to my big disappointment I found that there was no instrumentation. Anyway, then I started and got interested in the theory of consciousness. I had to study a lot of neuroscience. Three or four

people from other fields also joined me, and now we have an active programme in the area of consciousness research. Recently, a retired statistics professor from the ISI [Indian Statistical Institute] joined us. So that has become a very major programme at the NIAS.

You have even talked about the possibility of quantum biology.

Quantum biology, vacuum biology…

Have you initiated any work in these fields?

That is what we are doing now. It is a new field that has just come up. Quantum vacuum biology. See, the recent discovery of the Higgs boson has enormous implications for philosophy because this is where our idea of the universe is changing quite a bit. What we thought the universe was is only about 5 per cent. The remaining 95 per cent is in a form that we don't know. But even to understand the existence of this 5 per cent, and its formation, you need this 95 per cent being there in the form of energy. So energy has become the governing factor in the whole business of creation. The ultimate constituent somehow seems to be energy. That energy is probably in the form of quantum mechanical waves, which we call vacuum. Vacuum is not the absence of everything. It is the presence of everything in the form of energy. And it is the interaction of these energy waves… [trails off]. The other serious limitation we have is that we can only cognise three dimensions of space and one dimension of time. We can't even cognise four dimensions. Even four-dimensional space-time we cannot cognise. So reality seems to be operative in higher dimensions. We are seeing the projection of it in three dimensions. For any observation to be made, we have to reduce it to its three-dimensional consequences.

Something like string theory…

String theory may be in 10 dimensions. But we cannot design an experiment in 10 dimensions. We have to reduce it to its effect in three dimensions and one dimension in time. So far it has not been possible to do that in string theory.

So you think there is a kind of relationship between what you call reality and what you call consciousness?

Yes. Ultimate reality seems to be the quantum vacuum. The manifestation of quantum vacuum in three dimensions is what we see as our world. What is Sankara's philosophy? He said everything is Brahman. The manifestation of Brahman is what we see as Jagat. In the final analysis, there is a lot of similarity between what we are finding in terms of science as reality and what our philosophy says. Not only us, even Plato said the same thing. What you see is only the two-dimensional shadow of what is beyond. If you really want to know what is reality, you have to go outside and see, and not just see the shadow. That seems to be the case as far as ultimate reality is concerned. It seems to be in higher dimensions. Otherwise, by now we should have reached somewhere [in our understanding]. Problems in quantum theory, problems in relativity are all probably because we are operating not in reality by itself but in its projections in three dimensions. We have to work backwards.

In one of your reminiscences about Bhabha, you talked about the dream you had on the night of January 24.

That was the night of the day [in 1966] when Bhabha died. I was at Boston, and early morning my colleague telephoned and asked have you been following the news? He had listened to the radio, and there in the U.S. I was not very particular about listening to the radio. Radio had said that Bhabha had died in an air crash. I was very upset and did not talk further. In fact, on that day I was to give a talk in MIT on particle-antiparticle production in cosmic rays. And antiparticles had not been discovered at that time. So Phil Morrison, who was the colloquium chairman, had organised the lecture. I told him that I was very upset and I cannot give this talk.

He said, "No. You should give this talk and dedicate it to the memory of Bhabha." Then I gave the talk. That night I got the dream. In that dream Bhabha was dressed like a Parsi, with a black topi and white dress. And he was sitting in a chariot, which was like Krishna's chariot, and was airborne.

Since you are from a family of Ayurvedic scholars, may I ask what is the secret of your health?

There is no secret. I just happen to be healthy. Right from the beginning I have certain principles. I don't smoke, I don't take non-vegetarian food. I don't think they are responsible for all this. But I have stuck to a minimal set of principles. I used to regularly do one and a half hours of walking every day right from when I was 30 years or so. But now it is becoming a little difficult for the last three-four months. The other thing is I try to keep myself active. I don't say that I have now retired and I should go. I am not retired. Even now I go to the NIAS at 9:30 and work till 4:30 and then go home. That has helped me to be mentally active. I think the most important thing is luck. There is no other secret.

Wish you many more years of healthy and active life. Thank you very much.