Econometric Theory, **27**, 2011, 373–411.
doi:10.1017/S0266466610000319

THE ET INTERVIEW: B.L.S. PRAKASA RAO

Interviewed by Arup Bose[1]
Indian Statistical Institute



B.L.S. Prakasa Rao

Bhagavatula Lakshmi Surya Prakasa Rao was born on October 6, 1942, in Porumamilla, Cuddapah District, in Andhra Pradesh, India. He received his B.A. (Hons) from Andhra University in 1960, an M.Stat. from the Indian Statistical Institute (ISI), Calcutta, in 1962, and his Ph.D. from Michigan State University (MSU) in 1966 under the supervision of Herman Rubin.

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He spent 8 years in the United States and Canada at various universities. In India, he was a faculty member at the Indian Institute of Technology, Kanpur (IITK), for 8 years, followed by 28 years as professor, director, and Distinguished Scientist at the Indian Statistical Institute, New Delhi and Kolkata. He has been on the faculty of the University of Hyderabad since 2004 as visiting professor and is presently the Dr. Homi J. Bhabha Chair Professor there.

Prakasa Rao has served on the editorial boards of various international journals and is the recipient of several distinguished awards and honors. Most notable are his fellowships in the three science academies of India and the Institute of Mathematical Statistics, the Bhatnagar Prize, an Outstanding Alumnus Award from Michigan State University, and the Professor P.V. Sukhatme National Award.

Prakasa Rao's research contributions are in the areas of probability, stochastic processes, and mathematical statistics, especially nonparametric functional estimation, inference for stochastic processes (on which topic he has supervised two Ph.D. students), and asymptotic theory of statistical inference. He has published more than 200 research papers that are widely cited and has authored, coauthored, and edited 12 books. Prakasa Rao continues to be very active, and his current research interest lies in statistical inference for processes driven by a fractional Brownian motion.

The following interview with Professor Prakasa Rao took place on February 16 and 17, 2009, in his office at the University of Hyderabad.

How was your life as a child?

My father, Bhagavatula Rama Murty, was deputy inspector of schools, which involved transfers from place to place after every 2 or 3 years. My father and my mother, Saradamba, did not like this nomadic life for me as they thought my education might be affected. They sent me to live with my maternal grandfather, Kachinadham Venkata Subrahmanyam, until I completed my high school education.

What were your early school years like?

High school?

You had no schooling before that?

That is right, I had no formal elementary schooling. I joined high school in the sixth grade at the age of 6 and completed S.S.L.C. (secondary school leaving certificate) at the age of 12. It was all in the Telugu medium of instruction except for English, which was the second language. And then suddenly we all had to change to English as the medium of instruction when we went to college. But you know, we were able to make the transition. So, it is not true that you have to be taught English right from the beginning. I am a strong believer of that.

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It seems when you think mathematics, you think in your own language, the one you grow up with. For example counting . . .

Right. But coming back to high school. Being a town of only 5,000, there were just 300 students in the school and about 50 students in each class. So it was a small school, and we got personal attention. I was first in school. Then I had to go for my intermediate studies at Government Arts College, Cuddapah. That was 50 miles away. Then I went to Andhra University in 1957 to do my B.A. (Hons) degree and stayed in a hostel again for 3 years. And so I stayed in hostels from the age of 13. In fact my family says (*laughs*) it doesn't matter to you where you stay and what you eat, you have always been outside home all your life (*laughs*). After the Andhra University hostel, I stayed at the ISI hostel during my M.Stat. program and then on to catering for myself in the U.S.

You are a vegetarian?

Yes, I have always been a vegetarian. In those days life was tough in the U.S. for a vegetarian. I tell my son there was no e-mail, no telephone. Letters from home took 3 weeks, then another 3 weeks for a reply! I wonder how parents coped with it. In fact when I went first to the U.S., it took about a month for them to know that I had arrived safely. My wife asks me, how could your parents send you off under such circumstances? Food was a problem, but Sethuraman (J. Sethuraman) was a great cook. He was already at MSU as a postdoc, and so when I arrived, we shared an apartment in the first year. In my second year, he left for Stanford.

Do you know he is writing a book?

Really?

Yes, I saw that on his Web site. On Bayesian nonparametrics, covering topics such as Polya priors.

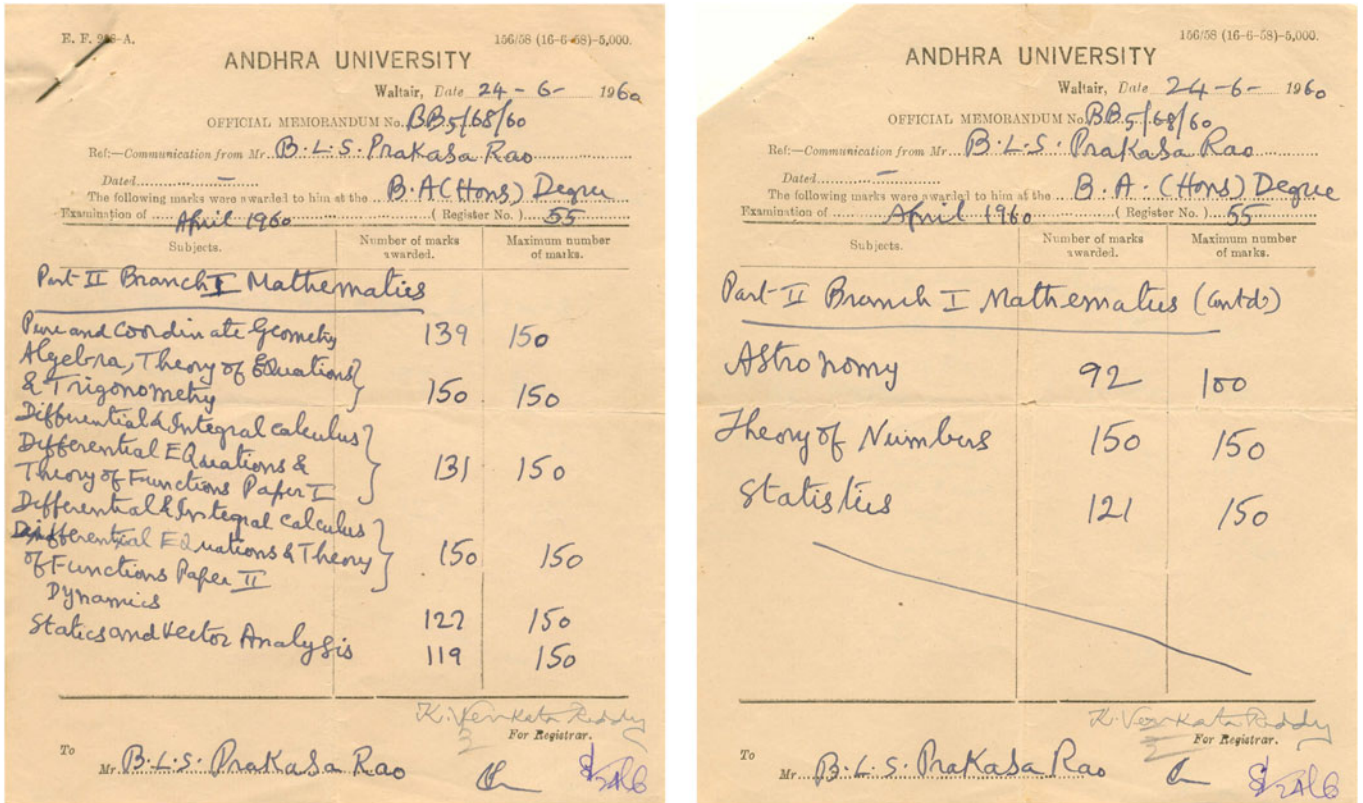
Sethuraman was a postdoctoral fellow at MSU when I went to do my Ph.D. I could go and talk to him about my doubts. Then he went to Stanford. Before that he was at Chapel Hill, then MSU, and then on to Stanford. He came back to India and went abroad again to join I.R. Savage's group.

After your M.Stat. at ISI in 1962, you went to MSU in 1963.

Yes. G. Kallianpur (GK) was there. I wanted to work with him. After my M.Stat. at ISI in 1962 with advanced probability as my specialization, I joined ISI as a research scholar. Dr. Rao (C.R. Rao) suggested that I look at the thesis by Parzen (Parzen, 1954) on uniform laws of large numbers and consistency dealing with maximum likelihood estimator (MLE). Parzen was a student of Le Cam, I think. So for a year I did that. GK and C.R. Rao had a paper on Fisher consistency (Kallianpur and Rao, 1955). Then a friend of mine, T. Krishna

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ANDHRA UNIVERSITY

Waltair, Date 24-6-1960

OFFICIAL MEMORANDUM No. BB.5/68/60

Ref:—Communication from Mr. B:L:S:Prakasa Rao

Dated —

The following marks were awarded to him at the B.A(Hons) Degree Examination of April 1960 (Register No.) 55

Subjects.	Number of marks awarded.	Maximum number of marks.
Part-II Branch I Mathematics		
Pure and Co-ordinate Geometry	139	150
Algebra, Theory of Equations & Trigonometry	150	150
Differential & Integral calculus Differential Equations & Theory of Functions Paper I	131	150
Differential & Integral calculus Differential Equations & Theory of Functions Paper II	150	150
Dynamics	127	150
Statics and Vector Analysis	119	150

K. Venkata Reddy
For Registrar.

To Mr. B:L:S:Prakasa Rao

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Subjects.	Number of marks awarded.	Maximum number of marks.
Part-II Branch I Mathematics (contd.)		
Astronomy	92	100
Theory of Numbers	150	150
Statistics	121	150

K. Venkata Reddy
For Registrar.

To Mr. B:L:S:Prakasa Rao

FIGURE 1. Andhra University record-breaking B.A, (Hons) marks sheet (1960).

Kumar, went to the U.S. for a Ph.D., and I decided I would also go to the U.S. for my Ph.D. MSU offered me a teaching assistant (TA) position, and Florida State offered admission but without a TAship. I chose MSU. But then GK had left East Lansing by the time I arrived (*laughs*), and so my plans of working with GK did not materialize.

My travel to the U.S. in 1963 itself is interesting. I did not have sufficient finances to travel to East Lansing. MSU offered a travel loan which I repaid after I went there as a graduate student. Without such support, I would not have gone, and this interview would not have occurred. I wonder how many universities would have given such timely help to an unknown Indian student. I thanked MSU for this when I was awarded their Outstanding Alumnus award in 1996.

When I was at MSU, Herman was giving a few courses, and I took one or two of them. You must have heard his lectures.

Yes, a few when I was at Purdue.

Of course I got A grades and all that. I went to Herman and told him I wanted to work with him. He told me that I had to pass the comprehensive first before we could discuss that. Well, I passed and went back to Herman and became his research assistant. I finished my Ph.D. in 2.5 years, and after I completed the work, Herman said that it was enough for two Ph.D.'s. That was very satisfying.

Then I had to come back to India because of a personal tragedy. My father had passed away in April 1966. But I had already made a commitment to join the University of California at Berkeley as acting Assistant Professor before that event had happened. So I went to Berkeley and spent about a year there, followed by another year at the University of Illinois, Urbana.

Then I was offered a job at the IITK.

Why did you choose Kanpur?

Actually the ISI had also offered me a position. But IIT had offered the additional incentive of paying my travel expenses to come back to India, which was substantial in those days. They also offered some other incentives, and better pay.

Any particular reason why you wanted to come back to India?

The primary reason I came back was family. My father had wanted me to come back. Many of my friends stayed in the U.S. of course. IITK was just starting up. J.D. Borwanker was the first to join. In fact I joined in 1968, 2 days after he did. Along with P.C. Joshi, we started the Statistics M.Sc. program at the department.

Le Cam had invited me in 1973 to be a research attaché at the Center for Research in Mathematics in Montreal, Canada, while he was the director. However

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FIGURE 2. Gathering at Berkeley symposium, 1965. Some of the people are as follows. Front row, left to right: (4) Elizabeth Scott, (5) B.L.S. Prakasa Rao, (6) John van Ness, (7) C.R. Rao, (8) V.K. Murty, (9) Jagdish Rustagi. Second row, left to right: (1) Shanti Gupta, (2) H.W. Tucker, (7) John Tukey, (8) Herman Rubin, (10) Peter Huber, (11) Madan Lal Puri, (12) Herman Chernoff, (13) Jerzy Neyman. Other rows behind: You can spot J. Sethuraman, A. Dvoretzky, Hira Lal Koul, Stephen Stigler, Z. Govindarajulu, P.S. Puri, and Habib Salehi.

he left by the time I joined. After I returned from Canada, things did not work out at IITK in the way I thought. There was an issue with promotion. By that time, ISI had started its Delhi campus. C.R. Rao said, why don't you come? So I was there from 1976 to 2004 till my retirement, a long association of 28 years.

When did K.R. Parthasarathy (KRP) join ISI as faculty?

I think he joined sometime around 1978. As you know, he was also a student at ISI Kolkata. In fact KRP and S.R.S. Varadhan both were Ph.D. students when I joined ISI as an M.Stat. student in 1960, and they taught me. Then KRP went to the Soviet Union for 1 year. From there he went to Manchester, to Bombay University, to IIT Delhi, and finally to ISI Delhi (ISID). On the other hand, Varadhan went to the Courant Institute and stayed there.

And when did K.B. Sinha (KBS)[2] join ISID? Was it within a year of KRP's joining?

Probably a year or two after KRP or around the same time. I don't remember.

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So, you joined ISID in 1976. In contrast, I joined ISI as a first-year B. Stat. student in 1975!

(*Laughs*) So KRP was a research scholar when we were students at ISI Kolkata. Sujit Mitra was also my teacher. He taught large-sample theory. C.R. Rao taught linear models. Those days it was called small-sample theory as opposed to large-sample theory! We had R.R. Bahadur, D. Basu, C.R. Rao, Sujit Mitra, and R.G. Laha as our teachers. For a student of statistics, what more could one ask for!

Was I.M. Chakraborty there during your time?

No, I think he had left before I joined. Laha, Roy, and Chakraborty had these notes, collected problems, what would now be called case studies. I do not know whether they are still available, perhaps John Wiley published them later.

When did the famous Rao, Mitra, Mathai table (Rao, Mitra, and Matthai, 1966) come into being?

That was much later, after we had left. Oh, I do remember the days of punch cards.

But you never got the hang of it?

No. We did computational work during our M.Stat. program using the good old FACIT.[3] But my main interest was in the mathematical side of statistics.

You liked the Greek symbols better?

Yes (*laughs*).

You have several brothers and sisters.

Yes, we are five brothers and four sisters. I am the eldest. My father passed away when I was only, let me see, 23. I had to take care of all of them. That is another reason why I came back to India. Now one of them has settled abroad. One brother has an M.Sc. in nuclear physics and was the principal in a local college, now retired. One is a doctor, an anesthetist. Another is a professor in electrical engineering at Carnegie Mellon. He did his B.Tech. and M.Tech. in IITK when I was there. He has interests in signal processing and pattern recognition.

So he is close to statistics.

Yes. One brother works in a bank. One sister has a Ph.D. in applied mathematics. Except the brother at Carnegie Mellon, all are now settled in Andhra Pradesh.

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And your family?

I got married in 1971. My wife, Vasanta, is the backbone of my achievements if any. I have three sons. One is working for Motorola, Bangalore, another is in Nokia, and the youngest did an M.Tech. in electrical engineering at the Indian Institute of Science at Bangalore in electronic design and technology and now is doing his Ph.D. at the University at Washington. He works in the hardware part of computers, not software. So they have chosen their paths and are on their way.

You were talking about Urbana.

Yes, my father wanted me to come back to India. Well, actually several of us had come back to India in those days. I had very limited time to spend in the U.S. after my Ph.D. I decided to visit the most happening places for statistics. Visits to the University of Illinois at Urbana and the University of California at Berkeley were very helpful.

As a part of my thesis, I considered the problem of estimation of the location of the cusp of a continuous density. The method of approach was itself new. It was through the study of the log-likelihood ratio process and its weak convergence. Le Cam was happy to hear about these results and talked about them in his colloquiums and seminars and wrote about them in his books on asymptotic statistics (Le Cam and Yang, 2000). Life at Berkeley was exciting. It was the time of hippies and flower children. It was also the time of the civil rights movement. At Berkeley, I attended courses given by Le Cam, Freedman, and Blackwell.

My visit to Urbana was also very exciting. Even though I had a tenure track offer from Florida State University in 1967, I preferred to take up a visiting position at the University of Illinois just to hear and learn from courses and lectures from stalwarts like Doob and Burkholder. I attended lectures by Doob on potential theory, by Burkholder on stochastic approximation, and learnt a lot. Another interesting experience was going out with Doob and Colin Blyth and other colleagues from the mathematics department trekking in the woods around Champaign every weekend and participating in Doob's seminars on Tuesdays with pizza lunches after the seminars.

That is why I did not want to go to other places. My time in the U.S. was short, so I wanted to make the most of it. I went to Stanford during 1964–1965 to work with Herman Rubin where he was on sabbatical from MSU. That visit to Stanford as a student was very helpful. I attended courses given by Chernoff on large-sample theory, by Stein on decision theory in statistics, by Kai Lai Chung on probability, and then there was Katznelson on harmonic analysis. Simultaneously I was carrying on my own research.

It turned out that Chernoff's paper on estimation of mode was published in the *Annals of the Institute of Statistical Mathematics* in 1964. My work on estimation of a unimodal density was inspired by that paper.

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It seems you got the best everywhere you went.

I always insist that a student should have a good mathematics background to be a good statistician. They can go anywhere after that. I have an open mind about applied statistics. But I think ISI has diluted its program significantly from the time when we were students. The amount of effort that we had to put in! Now it is quite reduced with the B.Stat. only requiring 3 years, and so it is not at the same level as earlier. For example, you can get an M.Sc. in Statistics or M.Stat. without knowing anything about sampling. That is not good. We had to prepare schedules and do sample surveys in Giridhi[4] and Baranagore[5] as a part of our practical experience for the course on sample surveys during our student days at ISI!!

Especially given that they are now coming to college after 12th grade. They already have had substantial exposure to calculus, and even statistics.

That's right.

Tell me, how did your directorship of ISI come about?

(*Excitedly*) Well, a lot of people think I left the directorship of ISI after three years of joining because of problems at ISI. Let me explain. In 1992, the University of Hyderabad offered me a Jawaharlal Nehru Professorship.

How does that professorship work?

At that time there were two chair professorships at this university: the Jawaharlal Nehru Professorship in the sciences and the Radhakrishnan Professorship in the humanities. The university invites persons of repute, offering a 2-year position at a full professor's salary with contingency. When the University of Hyderabad contacted me, I said I would not be able to come for the full 2 years, because my family was in Delhi, but would come for 6 months. And then this offer of the ISI directorship came along, and so I curtailed my stay in Hyderabad to 4 months. You may remember, during these 4 months the book *Stochastic Processes and Statistical Inference* [8] edited by B.R. Bhat and me came out, to which you contributed, and I also taught a course here. Then I went to Kolkata as the director.

No one contacted you before you were offered the directorship?

Not really. But S.B. Rao[6] came to me and said that the Stat-Math Division[7] was interested in having me as the director. But I did not formally apply. You see the Council of the Institute forms a committee who can propose and invite anyone. I do not exactly know how it came about. It could be that Professor S.K. Mitra might have suggested me, as I had worked as the head of the ISID center.

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FIGURE 3. Working in his office at ISI Delhi in 2004.

For how long?

About 6 months and I had also officiated in that position several times. May be through that they saw how I approach things. But I never applied formally. I accepted the directorship and went to Kolkata. Then my family joined me. I was the director during 1992–1995. As you know, the birth centenary celebrations of P. C. Mahalanobis[8] were held in 1993. My second son was in 10th grade in high school in Kolkata at the time. Then, 2 years later, he wanted to choose computer science as a specialization. I thought I should provide my sons with the best opportunities, so I sent them back to Delhi. I stayed on for 8 months after that, but, it was difficult to manage. The Delhi-Kolkata trips back and forth were not working. I visited them whenever I had meetings in Delhi. Some people thought I left Kolkata because I could not take the heat anymore. Actually, I did not have any problems on that count.

I recall one or two incidents. An agitation of some sort. And the faculty went and met you in support. I was in that group, at the back, being a junior faculty member!

Yes. The issue was having the binding of library volumes done outside. That was a major decision. Doing the printing of *Sankhyā* outside the institute was also a crucial decision. You see this had to be done. Otherwise *Sankhyā* would have

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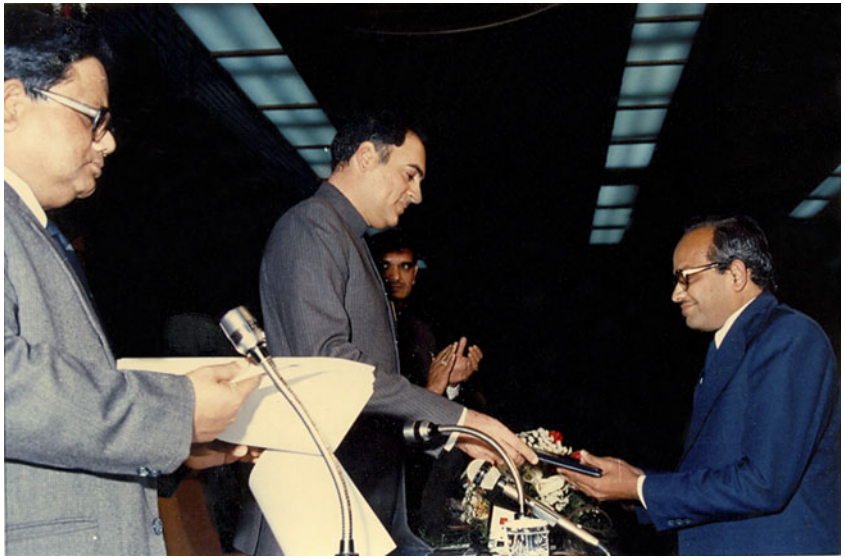


FIGURE 4. Receiving the Bhatnagar Award from the prime minister of India, Shri Rajiv Gandhi, in 1984.

stopped coming out. Then the cart carrying the library volumes for binding outside was stopped by some workers of ISI at the gate of ISI.

How did you handle the situation?

Well, I just presented the comparison of outputs from within the institute and outside and told them that there was no other way. They said, how can you do this? You have to go by the book—the *Categorization Manual*[9]. I said this decision has nothing to do with the *Categorization Manual* and as the director I need to consider what is the right thing to do and make that decision. The accounts were also in a mess. I had to streamline them. In fact, the practice of having separate account numbers for different activities was started by me. The housing loans, for instance–there were, say, 7 lakhs available for disbursement, and they had disbursed about 15 lakhs. We had to put a stop to this. So, the account number that you see on any bill from Accounts now—that was started by me.

I could not spend all my time on research, but I was working, and I still published. Maybe I could have spent a few more years as director, but I did not want to put pressure on my son.

So, you could take the pressure of the directorship.

Oh, yes, that was no problem.

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Wasn't there a nasty incident of shouting on the campus where you stayed?

Yes, that is true. I was in the director's flat. A group of people were walking around the lake[10]. My children were around there, and they understand Bengali.[11]

Yes, due to their Bengali friends.

Yes. They came and told me that the people walking around the lake are saying things about me—that I am corrupt. If I was, I would have been a millionaire!! Later on, these people came and apologized. Atis Dasgupta[12] called me up and said they did not mean it. Even the ISIWO [ISI Workers Organisation] said those people did not mean that and retracted their statements. But by then the damage was done! My children were shocked.

That is sad.

So that incident hurried up my decision. Without this incident, perhaps I would have stayed for another 6 months. All in all my time as the director was good. I think the choice of directors for ISI has been good all along. However, the pressure on the ISI director is different compared to directors of other institutes.

Is he too close to everyone?

Yes. I will tell you a short story. At other places, the director has a separate house, sometimes off campus. At ISI, we do not treat the directors like that. He is one of the faculty members. That is the tradition. Once my nephew from IIT Kharagpur came to see me, and he was looking for the director's house/bungalow and he could not locate it. The director is asked to take care of everything. Then that becomes impossible. I recall once a person encountered a snake on campus, and he brought it to my apartment. He wanted me to take care of it!

What is your favorite work among your contributions?

My thesis, "Asymptotic distribution in some nonregular statistical problems," has two parts, and I am happy with both. The first part is on the location of the cusp of a continuous density of the form $C(\lambda)\exp\{-|x-\theta|^{\lambda}\}$ where $0 < \lambda < \frac{1}{2}$. The rate of convergence here is $n^{-1/(1+2\lambda)}$, unlike in the classical case where it is $n^{-1/2}$. That is for the maximum likelihood estimate of the parameter θ when λ is known . . . (*goes to the board and explains*). When $\lambda = 1/2$ you get the regular case. The other cases are the nonregular cases. This is quoted in Ibragimov and Khasminski's book (Ibragimov and Khasminski, 1981). The method I used was through the limit of log-likelihood ratio processes. Then, for the shape restrictions on the density, there is cube root asymptotics. I obtained the limiting distribution of the nonparametric MLE when the density is either unimodal or when the failure rate of the density is monotone. These are my best works, and they had the main impact. I proved that $n^{1/3}$ is the right scale factor for obtaining the

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FIGURE 5. Meeting with the president of India, Shri R. Venkataraman, in 1992.

limiting distribution of the MLE. This has later led to the general study of cube root asymptotics. My other favorite area is inference for stochastic processes, as a subject over the years.

I worked on inference for stochastic processes, especially for diffusion processes, and now fractional diffusion processes. I published several papers and books covering this area, and M.N. Mishra collaborated with me on some of my works. Ishwar Basawa and I were probably the first to publish a book on inference for stochastic processes [1]. That itself is a short story. Basawa and I never met and did not know each other before our book came out. I wrote a technical report of about 150 pages, "Statistical Inference for Stochastic Processes," while I was at the Centre for Research in Mathematics, University of Montreal, which was privately circulated. Ishwar was working on a book on inference in applied stochastic models while he was in Manchester and suggested that we combine our efforts. That is the story behind the book. I met Ishwar at a conference in Delhi much later. The book has had a large impact on developing the subject of inference for stochastic processes all over the world.

Book writing is generally a thankless job. People think that you start writing books when you do not have much original research to do. I disagree. KRP told me that whenever you give a course, you should write up the lecture notes. I started following that maxim. All my books were the first ones written in those areas.

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My book *Nonparametric Functional Estimation* [1] dealing with density and regression function estimation had a wide impact among statisticians as well as econometricians. The book *Identifiability in Stochastic Models* [5] is quoted in the economics literature in their discussion on auction models. The books *Statistical Inference for Diffusion Type Processes* [10] and *Semimartingales and Their Statistical Inference* [9] have been well received by researchers in probability, statistics, and mathematical finance. I have just finished the book *Statistical Inference for Fractional Diffusion Processes*, dealing with statistical models for long-range dependence [12]. My book *Asymptotic Theory of Statistical Inference* [4] deals with inference problems via stochastic processes. I have also written a textbook, *A First Course in Probability and Statistics* [11] for undergraduate students with a 1-year course in calculus after my experience of 42 years of teaching students in India and abroad.

You have spent most of your time in the area of inference for stochastic processes.

Yes. When you work on inference problems for stochastic processes, stochastic process theory is involved in a natural way. Jeganathan used to work with me. He was there in Delhi for 2 years. Then I went to Madison and he moved to Kolkata. The idea of locally asymptotic mixed normal (LAMN) was started by me. Coinage of that term was also probably by me. He has a paper in that area (Jeganathan 1982). At the time Basawa's group was also working in nonergodic models leading to LAMN.

Basawa has a monograph.

Yes with Scott (Basawa and Scott, 1983). I told Jeganathan to extend the locally asymptotic normal likelihood to LAMN. He has a paper in *Sankhyā* on it, (Jeganathan, 1982), and even though my name is not there, that was started by me. Then he went to Kolkata, and he worked on martingales and other things. I have also worked in problems of inference with discrete data or data sampled from stochastic processes. I have done quite a bit of work there. I wanted to start a journal in this area. Then Denis Bosq started one, *Statistical Inference for Stochastic Processes*. I think these are my contributions. I am happy that all this has helped to create a subject, inference for stochastic processes.

Three years after you left Kolkata when your sons were better placed, did you think of taking up the directorship again? Or was the time not right or had passed?

I was quite young (49 years) when I took up the directorship of ISI. I could have done two terms if offered, but once I went back to Delhi, there was no point.

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J.K. Ghosh has done two with a gap in between.

Yes. But then I worked on two books published in 1999 ([9], [10]) after I left the directorship in 1995.

Of course, you have been very productive.

Yes, I used the time in a proper way. My full term as director would have ended in 1997. I went back to Delhi from Kolkata in 1995. I used up the time between 1995 and 1998 in writing two books. In hindsight, I should have continued so that my commitment would be complete. That thought came to me a little while later. But it was difficult you see, the rule being that the director must stay at the Kolkata center. And my family stayed in Delhi.

But some directors have been away for about 6 months a year.

I would never do that. Others have done it, but it is not ideal. You see five times six is 2.5 years out of 5. That is not good.

Yes, especially given the structure, if the director is not there, nothing works.

If you spend 6 months abroad and 6 months here, well, that is not a commitment to ISI. Also, you see, earlier directors B.P. Adhikari[13] and Ashoke Maitra[14] each had 3-year terms. Even GK was there for 3 years.[15]

So, the shelf life seems to be three.

True, but KBS was director for 5 years, as was S.B. Rao. I would have had some more years left after two terms if I had continued as director. I did not have time for book writing. But research-wise I did all right. I was the editor of IJPAM [Indian Journal of Pure and Applied Mathematics]. I used to fly to Delhi and work for the journal during the weekend and come back to Kolkata. I was also the editor of publications for INSA [Indian National Science Academy]– overseeing the publication of all their journals during that time.

I have been here for 5 years. I shall continue as the Homi Bhaba Chair Professor for one more year. I will be 68 by the time my term ends, and then I will see what to do. I am writing one more book.

Have you decided on a topic?

Yes, fractional diffusion processes. It will be published by Wiley, London, in 2010 [12]. But textbook writing is over. My textbook *A First Course in Probability and Statistics* [11] was published last year. That was just to keep myself busy.

Let us continue our chat tomorrow.

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FIGURE 6. In front of the bookshelf containing books authored by himself. Photograph by the interviewer at the University of Hyderabad in February 2009 on the first day of the interview.

Yesterday we did not talk about any of your students.

I had one in IIT K, M. Sivaprasad. He worked on inference in stochastic processes. The whole problem started with Billingsley (Billingsley, 1961). He extended things from independent identically distributed (i.i.d) variables to Markov dependence. After that no work was done, except for some attempts by B.R. Bhat (Bhat, 1974). I told him to work on inference for dependent random variables—the joint likelihood can be written as product of successive conditional likelihoods. Then, truncate the number of past observations at each stage of conditioning and consider the product of the conditional likelihoods based on truncated sequences. This gives rise not to m dependent type but to m_n dependent type sequences. He developed the asymptotic theory. B.R. Bhat from Karanatak University was the examiner of the thesis along with George Roussas. Then he joined the University of Pune and eventually left statistics and joined a computer center as its director in Kolhapur. Now he is the director of some computer center in a business school in Pune. So he has done well. His work was published in the *Journal of the Indian Statistical Association (JISA)* (Prasad and Prakasa Rao, 1976). There is a story behind that. Actually it was first submitted to the *Annals of Mathematical Statistics*. Ingram Olkin was the editor. He thought there was

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nothing much to do, since you still get normality and ergodicity. That was Olkin's thinking. Then we realized later that branching processes, for example, do not fit in the ergodic model and the MLE is not asymptotically normal. Sivaprasad also extended the Bernstein–von Mises theorem[16] to this general case (Prasad and Prakasa Rao, 1976). Parts of his thesis were finally published in *JISA*. Then Jeganathan worked in LAMN part of the time. Halfway through, when I was going abroad, he went to Kolkata. At that time Basawa was working in non-ergodic models, and I thought one could develop Le Cam's idea in mixed normal form. P.C.B. Philips was interested in LAMN models in connection with his work on multiple regression with integrated time series. Phillips was interested in Jeganathan's work, and I met him in Cornell in 1987 at the Conference for Inference for Stochastic Processes organized by N.U. Prabhu.

And also new time series models were coming out.

There were lots of such articles in *Econometric Theory*. Then of course Arusharka started working with me in Delhi after I came back from Davis in 1988. He did his M.Stat. in statistical quality control (SQC), but his interest was in research, not in SQC.

I wonder why he had chosen to do an SQC specialization.

I don't know. Anyway, T. Parthasarathy, who had taught him, suggested to him to meet me. Arusharka was not interested in working in linear programming[17].

Oh, so you had not taught him, and you did not know each other.

That's right. Around that time I was in Germany for a conference, and I met Winfried Stute, who knew of me and was working on conditional U statistics. So I suggested Arusharka look into it to see if there are hidden martingale structures and to see if this idea of reverse martingale so useful in U statistics could be used in conditional U statistics. So he was looking in that direction. At that time, he also read material on Vapnik–Chervonenkis classes. Then he wrote his thesis on conditional U statistics. He was very good. His papers came out in *Journal of Theoretical Probability* (Prakasa Rao and Sen, 1995b), *Sankhyā*, and *Statistics and Decisions* (Prakas Rao and Sen, 1995a); and now he is doing quite well. So it is true that ISI did not have many Ph.D. students, but when I went to Kolkata as the director, he came with me and finished his work there.

Yes, I remember that. I had been on leave, and I came back and he was using my office! And we started working together.

His thesis work was good and has been well appreciated. So these are essentially all the students I have had. I have some ongoing collaboration on random sums

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rates of convergence with Sreehari[18]. M.N. Mishra[19] and I are still working together on inference problems for stochastic processes. He comes here often. We are working on nonparametric estimation of trends of processes driven by fractional Brownian motion (fBm). I think I have about 15 papers with him.

Nice to know they are still active. You have done quite a bit of work with Isha Dewan also.

Yes. With Isha I have about 15 papers.

How did that happen?

When I was in Davis, there was a visitor from Arizona, A.L. Wright. He gave a lecture on associated random variables. Then I came back to India. Isha came from Chandigarh to do a postdoc and was planning to work with Prem Puri, but he passed away. So I told her why don't we look at the association property. Just like m-dependent, strong mixing variates, why not look at associated random variables and we subsequently submitted our paper to *Statistics and Probability Letters* [99]. At that time there was another paper submitted to the same journal.

By George Roussas?

Yes. He had submitted a similar paper (Roussas, 1991). That is how it started. So, both papers were published in the same issue, side by side. Isha and I have often talked about writing a small set of lecture notes, essentially on the estimation of the density function and other related problems for stationary associated sequences. We have also done work on probabilistic aspects such as rates of convergence. Isha and I have a review paper in the *Handbook* [143].

Now I am working on demimartingales. Martingales with finite moments are a part of the class of demimartingales. Partial sums of mean zero associated random variables provide an example of a demimartingale. You can prove all the analogues of the results for martingales—results such as the upcrossing lemma, the maximal inequality, convergence theorems, and the central limit theorem (CLT). We extended the notion to N-demimartingales, which is a generalization of partial sums of mean zero negatively associated variables. This has been published in the *Journal of Inequalities in Pure and Applied Mathematics* [191]. I have recently published a paper on conditional independence, conditional mixing, and conditional association [203]. You can develop covariance inequalities, FKG (Fortuin, Kastelyn, and Ginibre) inequalities, and so on. George Roussas has published a paper on conditionally associated variables (Roussas, 2008) (*shows a copy*). This is about extending standard results to those in a conditional framework. It may be noted that conditional independence and unconditional independence: one does not imply the other. The question then is, can you develop Kolmogorov's inequality, the law of large numbers (LLN), and so on, under conditioning.

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FIGURE 7. With the family: seen with wife, Vasanta; three sons; a daughter-in-law, and a grandson (2008).

Do these have any applications to time series models?

Yes, they do. If you have exchangeable random variables, then given the tail sigma field, the variables become i.i.d. So you have conditional results. The question is whether these notions of conditional mixing, conditional association, and so forth, have any applications.

So once you are in this framework, you have the LLN and get the CLT . . .

Well, the proofs are similar to the usual case. It is the idea that is important.

But you still have to carry through the arguments.

I gave some examples. Roussas has done similar things. Now my interest is in fBm. To develop results on estimation. You know my results in estimation in stochastic differential equations. Now, if you look at, for example, fractional Brownian sheet, there are open problems. In the one parameter indexed diffusions, you can stop a standard Wiener process to get any distribution with finite variance, the so-called Skorokhod embedding.

Yes, stopping by conditional variance.

That is called a random time change. In two parameters it does not seem to be true. There is no suitable past. So, what is the way out? I inquired all over the world.

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FIGURE 8. Receiving the P.V. Sukhatme Award from Sri Pranab Mukherjee, the Minister for External Affairs, Government of India, in 2008.

No one seems to know. Even for linear diffusion models, extending the results to random fields is not straightforward. I discussed the linear diffusion field case in the golden jubilee conference of the ISI. So, after so many years, I am trying the fBm version.

Yes, that was in 1982. You know the first two research papers that I wrote (Bose, 1983a, 1983b) were based on what you were doing at that time in diffusions.

Right. So, I presented this one in the Cochin conference.[20] I proved the Bernstein–von Mises theorem in this case and showed that the asymptotic behavior of the MLE and Bayes estimator are the same under some regularity conditions. Then there are these delayed time models. How to estimate parameters there? This has appeared in *Random Operators and Stochastic Equations* [198].

That has more practical implications in finance models.

I wrote on this in the Herman [Rubin] Festschrift [171].

The one edited by Anirban Das Gupta.

Yes. My interest now is on fBm and statistical inference for models driven by fBm. I have just completed a book on fractional diffusion processes that will be

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published by Wiley in 2010 based mostly on my work [12]. The problem is there is no one to work with here. There is no one working in probability. Journals are also few. But I manage.

Well, some of us can send anything that you need. Maybe I should renew my interest in this area. After all, that is how I started my research career.

If you look at my vita, I have also worked in characterization problems. I maintain my interest in that area. Also the Borel–Cantelli type of work and extending results to the conditioning framework. Working with Isha was good; it was a good collaboration. And with M.N. Mishra I have about 15 articles. These papers may not be pathbreaking but were fruitful. I still consider the parts of my thesis and the work on inference in stochastic processes as the most satisfying. Now, there is a branch of studies called cube root asymptotics. Of course the work using log-likelihood ratio processes for studying the asymptotic properties of the MLE in the nonregular case was pathbreaking when it was discovered. Herman Rubin was my guide and mentor in all of these efforts. Working with Herman itself is a miracle. Those who are familiar with him know how difficult it is to think along with him and how fast and adept he is in attacking a research problem. Herman is always bubbling with new ideas. I greatly benefited as his Ph.D. student at MSU. However I did have a problem getting recommendation letters from him for positions as Herman does not believe in writing per se! He did recommend me for the position of acting assistant professor at Berkeley after my Ph.D. by calling up Henry Scheffe, who was chairing the statistics department at Berkeley in 1966.

Regrettably our time is up. It has been very nice talking to you.

It has been nice talking to you, Arup. Thanks for your interest.

NOTES

1. My good friend and colleague P. Jeganathan, who was instrumental in initiating this interview, has sadly passed away in January 2009. The interviewer's research is supported by J.C. Bose National Fellowship, Government of India. Address correspondence to Arup Bose, Statistics and Mathematics Unit, Indian Statistical Institute, 202 B.T. Road, Kolkata, 700108, India; e-mail: bosearu@gmail.com

2. Director of ISI, 2000–2005.

3. These were mechanical calculating machines made in Sweden by Atvidaberg-Facit and were on the market until the early 1970s. See http://www.vintagecalculators.com.

4. An experimental station of ISI in Bihar.

5. Suburb of Kolkata where ISI is located.

6. Director of ISI, 1995–2000.

7. The academic activities of the ISI are organized into several divisions such as Applied Statistics, Biological Sciences, Computer and Communication Sciences, Library, Documentation and Information Sciences, Physics and Earth Sciences, Social Sciences, Statistical Quality Control and Operations Research, Teaching and Training, and Theoretical Statistics and Mathematics (Stat-Math).

8. The founder of ISI.

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9. It outlines the different positions at ISI and their job descriptions.
10. ISI Kolkata has five water bodies on its campus.
11. The local language of West Bengal, which is also the national language of Bangladesh.
12. A faculty of ISI.
13. B.P. Adhikari was the ISI director during 1979–1982.
14. Ashok Maitra was the director of ISI during 1984–1987.
15. GK was the director of ISI during 1976–1978. It is said that he never formally resigned from that post.
16. Convergence of the posterior distribution.
17. Several students have obtained Ph.D.s in linear programming and related areas under the guidance of T. Parthasarathy.
18. Retired from M.S. University, Baroda, Gujarat.
19. Retired from Sambalpur University, Sambalpur, Orissa.
20. International Symposium on Probability Theory and Stochastic Processes in Honour of Professor S.R.S. Varadhan, Cochin University of Science and Technology, Kochi, India, February 6–9, 2009.

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