



Anveshanā

VOL 2 • ISSUE 2

JULY 2026



IN CONVERSATION WITH

•
PARTHA SARATHI CHAKRABORTY
RUKMINI DEY
K.K. SURESH KUMAR

KNOW, WE MUST. KNOW, WE
WILL.

•
PROGNADIPTO MAJUMDER ON
UNTYING THE KNOT

•
SRUTHI SUBRAMANIAN ON
MATHEMATICS IN FINANCE



*Dedicated to those who dream boldly, venture endlessly, and
share generously*

In the Echoes of their Light

Benedict H. Gross (1950–2025)

Madhav Gadgil (1942–2026)

Anthony Leggett (1938–2026)

Mark Wise (1953–2026)

Asha Bhosle (1933–2026)

Ravindra B. Bapat (1954–2026)

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ANVESHANĀ

JULY 2026

Dear Reader,

Anveshanā began with a vision—to strive, to seek, to find, and not to yield. Borrowing Tennyson’s enduring words, we have sought, above all, to share that spirit of inquiry: the belief that a life is not merely lived, but consciously sought, continually shaped, and meaningfully shared. Every issue is an attempt to carry that vision a little further, bringing together stories, ideas, and conversations that celebrate the many paths through which a life of curiosity unfolds.

In this issue, we trace the beginnings of mathematical journeys, exploring how childhood curiosities and early encounters blossomed into lifelong pursuits in conversations with mathematicians Partha Sarathi Chakraborty (ISI, Kolkata) and Rukmini Dey (ICTS, Bangalore). In the same spirit, we peek behind the shelves of a well-established library, bringing to light the quiet efforts of those who shape the outreach resources of a distinguished research institute in conversation with librarian K.K. Suresh Kumar (HRI, Prayagraj). Along the way, we revisit the rise of quantitative thought, the role of mathematics in finance, and unravel the mathematics of knots.

We would also like to use this space to endorse an important declaration on the use of AI in mathematics: *Leiden Declaration on Artificial Intelligence and Mathematics*. In an age of instant solutions and assistance always at hand, one must reaffirm the need for slow, independent mathematical thought and for a genuine affection for the subject, not merely for its results. This issue echoes that sentiment at several places. That said, one need not be oblivious to the ways in which AI can help. Used with care and discernment, it remains a valuable aid, but never a substitute for human thought.

As always, we are grateful to the friends of *Anveshanā*, especially C. S. Aravinda, for his silent unwavering support. We also acknowledge every hand, seen and unseen, whose care has allowed this humble undertaking to continue.

We entrust this collection to you, allowing its many voices to unfold at your own pace. May each story offer a new horizon, and may your journey through them be a memorable one.

With warm regards,
Anveshanā

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KNOW, WE MUST. KNOW, WE WILL.

BY THE EDITORIAL BOARD

Is it truly the case that the scientific pursuit born of sheer curiosity lacks value? The question is older than science itself. “Curiosity, which may or may not eventuate in something useful, is probably the outstanding characteristic of modern thinking,” said Abraham Flexner in *The Usefulness of Useless Knowledge*. Before asking whether any knowledge is useful, one must ask what it means for knowledge to possess a use. Is the usefulness just the correspondence between the idea and the existing needs of a civilization? But one should not deny the right to be useful to any inquiry done, even if it does not bring any fruit to any immediate party. In a grand principle, it always does—in more than immediate and obvious ways. However, this is a bit of a strong opinion, something which largely pure mathematicians and theoretical physicists have maintained.

Mathematics, as a science or art, has been useful. From computer chips and navigation systems to family budgeting, it plays a subtle but clear role. But one is not required to understand group theory to read a clock. The usefulness of mathematics in daily life can be acknowledged on a terms basis. Yet the general public remains ignorant of its utility. While the same can be said of, say, biology or psychology, mathematics has suffered more than any other discipline from the accusation of being “useless.” Entire branches of algebra, number theory, geometry, and topology were cultivated for centuries without hope of practical reward. Euclid, Riemann, or Einstein were not building GPS; Newton was not launching satellites, nor was Grothendieck inventing cryptographic protocols. Their pursuits were personal and abstract, part of the grand scheme of knowledge and the progression of their subject. This is a beautiful irony: ideas developed purely for understanding these generalities can become the foundation of the very civilization that, at one time, ignored their utility and considered them unnecessary. One can, of course, accuse the examples presented here of being selective. However, we say that even if the pursuit is personal, the value of theoretical subjects lies not merely in what they can do in practice, but in what they allow humanity to become, and in how far they enlarge our capacity to ask new questions from old ones.

Fortunately or unfortunately, modern civilization has quietly replaced the pursuit of knowledge with utility as the measure of its importance. With research proposals requiring impact statements, universities seeking innovation, and students questioning the scope of a subject, the justification of usefulness has become the most important factor in evaluating any success.

The title of this editorial is inspired by David Hilbert’s celebrated declaration, “Wir müssen wissen. Wir werden wissen.” (“We must know. We will know.”). For full effect, you are encouraged to read the title in the voice of Yoda.

But this is a recent demand. Ancient civilizations like the Greeks or the ancient Indians would have found it peculiar. Yet this essay has been written in our modern world, so such a comparison is futile here, given how much our understanding of the word 'civilization' has changed. It may be that every age asks what knowledge can provide to their immediate needs.

While this is true in abstract sciences, and as we acknowledge our ignorance beyond them, we can speculate on the following questions for a large class of intellectual pursuits. Suppose a philologist reconstructs a forgotten script, as Jean-François Champollion did through his work on Egyptian scripts in the Rosetta Stone. Suppose a musician devotes a life to a raga, much like Ustad Asad Ali Khan. Suppose a philosopher and scholar spends years understanding a single fact or truth, in a similar spirit to Adi Sankaracharya or Wittgenstein. What are their uses in the grand scheme of things? For a large, non-overlapping audience, they do not seem to have a return; yet if they disappear, the civilization becomes poorer. Their values lie in humanity's memory, not in produced commodities. Even after centuries have passed, creators' ideas still contribute to human thought. Perhaps this is the deepest usefulness of knowledge: not necessarily to serve the present, but to enlarge the inheritance of the future.

One need not claim that each inquiry into knowledge will transform the world; indeed, many may not. Yet sincere effort adds to overall understanding and offers a modest gift to posterity. This alone can serve as a reason for curiosity to wander. If there is a usefulness to what is often called 'useless knowledge,' it first lies in the confidence that understanding is itself a worthy and human endeavor.

ON THE POETRY OF SURFACES: INTERVIEW WITH RUKMINI DEY



Rukmini Dey lecturing at ICTS in 2025 *Ms NOEL MATOFF*

RUKMINI DEY is a mathematician and mathematical physicist at ICTS-TIFR, Bengaluru. Her research lies at the interface of geometry and mathematical physics, with a focus on quantization and optimization problems. She completed her PhD at Stony Brook University in 1998 under the supervision of Leon Takhtajan. Before joining ICTS-TIFR, she was a faculty member at HRI, Prayagraj. She is also a passionate poet and writer.

In this conversation with Purnima Tiwari and Aayush Verma for *Anveshanā*, Prof. Dey reflects on her childhood, her mentors, mathematics as poetry, her years at IIT Kanpur, the problem of quantization, the importance of outreach, and an academic journey shaped by geometry. We are also delighted to include a selection of her poems with this interview.

Could you tell us a bit about your childhood and the early interests that set you on your current path?

Rukmini Dey: I was born and brought up in Kolkata. I had a really special childhood. My parents, Mira Dey and Jishnu Dey, were both physicists and taught at Presidency College and Maulana Azad College. They would come home exhausted after traveling on crowded buses,

but then sit with their pen and paper and do research in physics. They had several papers, and looking up to them ignited a great interest in physics and research in us. However, at some point, I realized that mathematics, in particular, was extremely beautiful. There is something deep, serious, and extremely truthful about it. The simple fact that every line must be proved hints at its truthfulness. Later, I was influenced in a similar manner by geometry. It was the first place in our curriculum where proofs were introduced through elementary theorems. This fascinated me, and I thought there was something deep and serious that I wanted to learn.

Since your parents were physicists, did they actively share the nuances of their daily work with you?

RD: My parents were incredibly inspiring. Whenever they came across something exciting, they would share it with us over dinner. They also bought us various books. I remember one particularly fascinating book, “Why, What, Where”, that explained how things work. It covered the formation of stars, the main sequence, and extraordinary phenomena like neutron stars and black holes. I remember we were completely mesmerized by it all, which is why we three sisters wanted to study physics.



Rukmini Dey with her mother Mira Dey.
RUKMINI DEY

Would you say that was the starting point of your journey as a reader?

RD: No, we got into reading a long time ago. This was actually during my pre-teens, around class eight or nine. We used to be avid readers of English, Russian, and Bengali literature.

Were your siblings similarly inclined toward the sciences?

RD: Yes, my two sisters also pursued physics and are now both physics professors in the US, one at UCLA and the other at Louisiana State University. They do amazing work. My twin sister Joyoni specializes in medical imaging, interferometry, etc., at LSU, and my sister Damini is in medical physics at Cedars Sinai Hospital and UCLA.

“The simple fact that every line must be proved hints at its truthfulness.”

How important is early exposure and the presence of role models in shaping one’s scientific journey?

RD: Early exposure makes a big difference. Not only do you get to like the subject very early, but it also becomes a part of you and gives you confidence. There will be many tough things in life; there are times when people will

say you are not good enough, or you will get indirect messages that this is not suitable for you. But you keep plodding on because you know your parents/mentors did it. Having a role model makes a big difference. You see people plodding on despite all the negative obstacles, just for the joy of the subject.

You have mentioned that having a role model is vital. Who were the people who most influenced your mathematical journey at different stages of your life?

RD: Initially, my parents. Later on, for a brief while, Professor Karen Uhlenbeck was my mentor. Unfortunately, at the time, I was not in a position to learn much. But later, I kept in touch and indirectly learned a lot from her. Even though she was very far off, she would still reply warmly to my messages. I also really look up to another professor, Professor Dusa McDuff, who was at Stony Brook when I was a PhD student. She seemed to be the person of reason in this mad world. I followed their papers. They were my indirect, long-distance mentors.



Rukmini Dey with Rajesh Gopakumar in Bhutan. [RUKMINI DEY](#)

Who inspired you during your undergraduate years?

RD: Apart from my parents, Professor Shobha Madan of IIT Kanpur. She was a true inspiration and a friend. I also rediscovered the music and poetry of Tagore at that time. I met my husband, Rajesh [Gopakumar], there, and he gave me warm intellectual and emotional support.

What is your first recollection of listening to Tagore's songs?

RD: It is so ingrained in us. We do not know when it started. It's like sunrise for us. As soon as the sun rose, the radio would turn on. Every day during breakfast, three very good singers would sing Tagore songs on All India Radio.

Do you have a favorite song or poem by him?

RD: I have many favorite songs for different times and different moods. There are layers and layers of meaning. What a song meant to me as a teenager is very different from right now.

Beyond Tagore, what writers or literary traditions shaped you while you were growing up?

RD: My grandfather, Bishnu Dey¹, was a poet who deeply explored poetry and literature

¹Bishnu Dey (1909-1982) was a contemporary Bengali poet in the post-Rabindranath era. See his [Wikipedia](#) entry.

from around the world. My grandmother, Pranati Dey, used to read us Shakespeare's plays. We actually grew up on Bengali, Russian, and English literature. We read a lot of Russian books, starting from Tolstoy and Dostoevsky to Sholokhov and Turgenev. Russian history is so tumultuous, and the literature is very deep. Later on, during my undergraduate days, I was into reading Camus.

Has your relationship with literature changed over the years?

RD: Actually, this stayed with me for a long time. But somewhere in the middle of my career, I stopped reading literature. I do not know; it just could not sustain me beyond a point, except for Tagore's songs, which still uplift me. I just kept reading math books. Math is my new literature. Even if I do not understand it, I still keep reading.

Let us move to your undergraduate years. What was your experience like as a student at IIT Kanpur?

RD: I was in the five-year mathematics program at IIT Kanpur from 1987-92, and I really enjoyed it. I also met my husband, Rajesh [Gopakumar], there. I have to mention my teacher, who really inspired me at the time: Professor Shobha Madan. She was my topology teacher, and I remember her wise words even now. I also had wonderful friends, Reema, Sri-latha, Monika, Renu, Rita, whose words I remember even now.



Professor Shobha Madan. **IISER MOHALI**

Were you in the 5-year BS-MS program then?

RD: At the time, the five-year program was called an Integrated MSc, and admission was through the JEE.

Was Professor Gopakumar your batchmate? And what do you remember most vividly about student life at IIT Kanpur?

RD: Yes, he was also in our batch, studying physics. We hung around together a lot. There were beautiful villages outside the IIT Kanpur campus where we used to go for long walks.

When did you last visit IIT Kanpur?

RD: That was a long time ago. The campus has changed a lot – a lot fancier, but perhaps a lot fewer trees.

Yeah, fewer peacocks as well, but more dogs.

Coming back, although you were deeply interested in physics, what led you to choose mathematics?

RD: I was given [IIT] Kharagpur as an option. I had other choices, but I picked mathematics because I always liked it. I especially loved the idea of giving proofs. The fact that every single line has to be proven, and proven to be correct, really attracted me.

DANCE OF THE MIND

*Mathematics, the dance of the mind,
synonymous with truth. In that temple, I was
alone with mathematics, unjudged by people.
And as I was alone, the bird who nested in
the temple pillars chirped happily and told
me to hold water in my palm for as long as it
will stay, the holy water of symmetry and
harmony.*

— Rukmini Dey
The Oriole in My Garden

Despite choosing mathematics, you have remained closely connected to physics.

RD: I like working on problems with physical applications, but my work is mathematical and still not very practical.

Besides Professor Shobha Madan, were there other teachers at IIT Kanpur who had a lasting influence on you?

RD: Professor U.B. Tiwari was very respected amongst us. We looked up to him. And then there were several others, like Pro-

fessor H.S. Mani from the physics department. We were really influenced by his teaching. Then there were Professor Jayanta Bhattacharya and Professor Kalyan Banerjee, who were very good physics teachers. I remember learning about chaos, taught by Kalyan Banerjee, and I was just thrilled by it.

What did H. S. Mani teach?

RD: He taught us quantum mechanics.

Who were some of your classmates and friends from those years whom you still remember?

*“Math is my new literature. Even
if I do not understand it, I still keep
reading.”*

RD: Srilatha Ganesan and Anurag Kumar Singh were good friends. Now that they are married and in Utah. Anurag is a professor of mathematics at the University of Utah. Reema Chatterjee, Monika Agarwal, and Renu Mehra were also good friends of mine. Mahan Mitra, who is now Mahan Maharaj, was a batchmate and is a mathematician at TIFR Mumbai. I am still in touch with all of them. Rita Singh was a very good friend of mine, but we lost touch.

Were you drawn to developments in theoretical physics such as string theory?

RD: No, I was not going towards physics, though I did try to understand string theory a lot. I tried reading up on it, especially from a book by Nakahara, *Geometry, Topology and Physics*,

and Polyakov's books, but it did not work out. It was very attractive, but I had my doubts. I did take a few courses in particle physics, and that fascinated me, especially Noether's theorem.

Do you still think about string theory in the same way today?

RD: Actually, I do not know enough to judge. Right now, I am mature enough to just say that I really do not know. I try not to comment on other people's work which I do not understand. But I do believe one thing: if somebody is trying to understand the universe in a certain way, we should not discourage them. You just let people develop their tools, and maybe one day, it will all make sense.



An information panel at a museum in Bithoor, Kanpur, tracing the historical spellings of the city's name. *ANVESHANĀ*

Alright, let us go back to Kanpur. Did you also spend some time exploring the city and its surroundings beyond the campus?

RD: We did not go into the city much. But the areas just outside Kanpur were a different story. We loved exploring the outskirts because the villagers were so kind, and it was always such a pleasure walking around the Ganga canal area.

Were there other places around Kanpur that you particularly enjoyed visiting?

RD: Yes, we once cycled to Bithoor. We also used to go cycling a lot. A group of us would often cycle together down the Ganga. I remember Prof. Shobha Madan really enjoyed birdwatching, and I went with her to places where there were always plenty of birds.

Towards the end of my time there, I became very close with a friend, Rita Singh, with whom I used to walk a lot. Rajesh was also quite an adventurer, and we used to go to the villages.

You later returned to IIT Kanpur as a faculty member. How did that experience differ from your years there as a student?

RD: It was very different, of course. As a faculty member, you have so many duties, and I was really overwhelmed and quite lonely. But I had very good students. Some of them actually kept in touch. Professor Arvind Ayyer of IISC once told me, "I was your student, and I learned analysis from you." I still remember some of my students.

What subjects did you teach while you were there?

RD: I mostly taught real analysis and differential geometry; those two subjects stand out most prominently in my mind. I may have taught topology as well, though it was a while ago, and I do not remember precisely.

Let us move to your PhD at Stony Brook. What drew you there, and what research problems did you hope to pursue?

RD: I went to Stony Brook in 1992 because I specifically wanted to learn geometry, especially areas of mathematics that provided insights into physics. It was a very good experience. I worked under Professor Leon Takhtajan, focusing on two main areas. The first was a problem in mathematical gauge theory. The second was highly geometrical: prescribing Gaussian curvature on Riemann surfaces with punctures.

How did you choose this quantization problem?

RD: I was deeply fascinated by a visit from Maxim Kontsevich, who was working on Poisson manifolds and deformation quantization. That experience inspired me to learn more and to pursue quantization, specifically what it means for mathematicians. It is a bit different from the physicists' approach; it's much more formal. While mathematical work often finds a use in physics much later, its immediate utility is not always transparent. Still, I was completely captivated by the mathematical side of it. I ultimately focused my research on the geometric quantization of certain moduli spaces of Seiberg-Witten equations. My advisor [Leon Takhtajan] actually wanted my other project to be the focus of my PhD², but I really wanted to pursue this one. He gave me the freedom to do so, and it turned out to be incredibly fruitful. He would give very useful, broad hints, suggesting I look into a specific area or certain line bundles, but I had to work out the details myself. We would meet briefly every two weeks. He was a profound mathematician, and through the deep topics he taught in his classes, he helped me see the true beauty and depth of mathematics all over again.



With Leon Takhtajan and Vamsi Pingali at IISC Bangalore in 2017. **RUKMINI DEY**

Did his [Takhtajan³] background in the Russian mathematical tradition influence the way he mentored students?

RD: Yes, of course, but he was actually a physicist who later became a mathematician. In Russia, there is less distinction between physics and mathematics.

Quantization appears in several mathematical and physical settings. How do you think about deformation and geometric quantization?

²Thesis available at <https://www.math.stonybrook.edu/alumni/1998-Rukmini-Dey.pdf>

³An interview with Leon Takhtajan can be found in *Bhāvanā* July 2017 issue: <https://bhavana.org.in/leon-takhtajan/>.

RD: At very small scales, on the scale of Planck's constant, $\hbar$, quantization becomes necessary because quantum mechanics is the dominant reality in small scales. In the standard approach, observables like energy, momentum, and angular momentum are treated as operators acting on a Hilbert space. The quantum states live in this Hilbert space, the operators act upon them, and the states evolve according to the Schrödinger equation. While there are many other viewpoints nowadays, this is a starting point. In deformation quantization, we take the algebra of observables and quantize them by introducing a 'star product' which makes them naturally non-commutative. However, in the classical limit, as $\hbar \rightarrow 0$, this product simply becomes the ordinary product. Furthermore, the commutator becomes proportional to the Poisson bracket in the same limit.

When we say that $\hbar \rightarrow 0$ represents the classical limit, it simply means that the macroscopic scales of the problem are so much larger than Planck's constant ($\hbar$) that $\hbar$ effectively approaches zero. You can't take that limit in the quantum world because quantum scales are on the order of $\hbar$ itself. But when you are operating in a classical system, you can. In that limit, the star product becomes the usual product, and the star commutator becomes proportional to the

Poisson bracket. That, in essence, is deformation quantization.

"While mathematical work often finds a use in physics much later, its immediate utility is not always transparent."

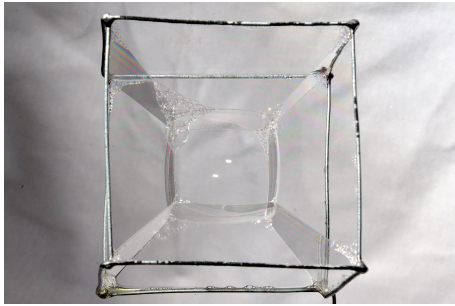
Another approach is geometric quantization, which is a beautiful subject in its own right. Geometric quantization occurs when you have a symplectic manifold, and its symplectic

form is integral. In that case, you can construct what is called a pre-quantum line bundle whose curvature is proportional to the symplectic form, and its sections are the wave functions. The observables (functions on the symplectic manifold) now act as operators on these sections. There is a specific way to define these operators so that they must satisfy the Dirac condition: the commutator of two operators is proportional to $\hbar$ times the operator corresponding to the Poisson bracket.

I am now trying to explore deformation quantization of non-symplectic manifolds by embedding them into certain special symplectic manifolds with a deformation quantization and then inducing the quantization from the ambient manifold. This is related to quantum information theory.

Could you explain the mathematical distinction between minimal and constant mean curvature surfaces, and the optimization principles behind them?

RD: Yes, that is another very interesting topic. Minimal surfaces are zero-mean curvature surfaces like the helicoid and the catenoid, and mathematicians have been studying them for 200 years. On the other hand, there are CMC (constant mean curvature) surfaces, such as the sphere, the cylinder, the unduloid, and the nodoid, which are also reflected in nature.



A soap film spanning a cubic wire frame forms an area-minimizing surface. By Ddg-
 FOTO THROUGH WIKIMEDIA COMMONS

Both categories involve integrable systems. I should also mention that there is an optimization problem behind all of this. For example, minimal surfaces locally minimize area. The optimization problem that guides CMC surfaces is a bit different. For those surfaces, the goal is to minimize the surface area given a volume constraint.

As an aside, Nature is always optimizing one thing or another under certain constraints. It's truly amazing. For instance, I recently became very interested in the growth of a lily. If you ever watch the ICTS talk⁴ "To paint the lily, mathematically" by Professor L.

Mahadevan from Harvard, you will see him explaining the exact mechanics of how a lily grows. That is an energy optimization problem subject to differential growth constraints.

Would it be fair to say that optimization principles motivate your geometric intuition?

RD: Not really so much. It's the geometry; I like the visual part. Optimization is something to ponder, and it feels right.

As an aside, I also work on maximal surfaces which optimize the Lorentzian area in Lorentz-Minkowski space,

Right. But their mean curvature is still zero?

RD: Yes, mean curvature in Lorentz-Minkowski space is zero for maximal surfaces. And they can have singularities, which is a feature of Lorentzian space. For instance, conical singularities, swallowtail singularities, etc.

Because of the negative part of the metric?

RD Exactly. By the way, recently, we have been able to connect CMC surfaces of revolution to certain number-theoretic objects, namely, elliptic curves.

Okay. That is interesting.

RD: We also sometimes see very surprising applications of number theory in geometry. For example, the minimal surface equation is highly non-linear. Because of this, if you add the height functions of two minimal surfaces together, you would not usually expect to get the height function of a third minimal surface. However, there is an Euler-Ramanujan identity

⁴Available at <https://www.youtube.com/watch?v=OYVckALM1I4>

that allows us to decompose the height function of Scherk's surface in terms of an infinite sum of height functions of shifted helicoids. This is known in liquid crystallography!

It is fascinating because, in research, you quickly find that you cannot restrict yourself entirely to geometry, even when geometry is your primary focus. Number theory showed up in geometry. Take another example. We worked on an interpolation problem: given two real-analytic curves, can you interpolate them with a minimal or maximal surface? To solve it, we found that the tools of functional analysis were needed. Everything is interconnected and useful.

Besides Professor Takhtajan, were there other mathematicians who influenced you during your time at Stony Brook?

RD: Professor Dennis Sullivan was there, which was incredibly interesting. Every tea time, he would hold informal seminars, sharing his theories and explaining his unique mathematical viewpoint to the graduate students who would gather to listen. Sometimes he would invite other professors to speak. For instance, I remember he once invited Professor Michael Anderson, who was making significant progress on the Poincaré conjecture at the time using Hamilton's method. He gave us a wonderful talk. We would often gather during tea time just to hear Dennis Sullivan's explanations. It was a wonderful experience listening to his unique viewpoints on various topics of mathematics.

Besides your advisor, who else influenced your mathematical development during your PhD years?

RD: I learned a great deal from my peers; they were truly amazing. I remember Carlos Florentino, who used to explain so much to me. I had Iranian, Russian, and Jewish friends who were all incredibly kind. At that time, America and its graduate schools felt like a great equalizer, bringing together people from all over the world. Along with my Indian friends, it was a fantastic, diverse community. I learned most of my math from my peers, really. I had wonderful Chinese and Korean friends. My roommates were always either Chinese, Korean, Indonesian, or Japanese, and I learned so much from them. It was not always about mathematics—it was about life.

"...in research, you quickly find that you cannot restrict yourself entirely to geometry, even when geometry is your primary focus."

How was it returning to India after your PhD? What differences did you notice between the research environments in the US and India?

RD: I felt a great sense of relief upon returning to India; it was my own country, after all. To be honest, I had been quite sensitive to the racism I experienced abroad, and coming home lifted that burden. Returning to a place like the Harish-Chandra Research Institute (HRI) was especially wonderful because it was so deeply connected to nature.

My colleagues were good to me, and I loved teaching. The best part was that we were all on the same campus, so we were students and teachers together, without much hierarchical distinction between us. We used to have music and poetry parties; it was just too good. But professionally, you are right that once you are on the faculty, you feel the politics a little bit. You start to see that this group is a little separate from the other one. There was no concerted effort between groups. And, of course, exposure to the rest of the world was not really there.

Despite those challenges, HRI seems to have been a very special place for you.

RD: I had a beautiful time in HRI. I must say. Some of my best graduate students were at HRI: Pradip Kumar and Rahul Kumar Singh. They are both excellent. Pradip is now on the faculty at Shiv Nadar University (SNU), and Rahul is at IIT Patna. They took up our research on minimal surfaces very seriously, and today, I am proud to say that each of them leads a large research group of their own.

After HRI, your career took you briefly to IIT Kanpur before ICTS. How did those transitions shape you?

RD: I spent some time at IIT Kanpur, but I found myself very lonely there. I moved back to HRI in a year or so.



Pictures from 2023 of ICTS. Left: Pāṇini library. Right: A tree. **ANVESHANĀ**

When Rajesh was appointed as the Director of ICTS, we moved to Bangalore. I also joined ICTS. Initially, I did not like moving to a big city at all. Compared to Allahabad, which was very personal and connected, Bangalore seemed quite impersonal. The language was also a barrier; I knew Hindi, but I struggled with Kannada, and I still do. It feels a bit foreign when you can not speak the local tongue. Beyond that, even the visible difference in the city's wealth levels was a significant adjustment.

It was just a matter of time to get adjusted, though. I tend to put down roots in a new place quite easily.

I am currently learning Kannada and have made wonderful friends. So, while the cultural differences seemed vast initially, I feel very settled now.

Is Kannada your fourth language, then—after Bengali, Hindi, and English?

RD: Indeed, Kannada is my fourth language.

How has ICTS shaped your experience as a mentor and teacher?

RD: It has been a great journey. One important thing I should mention about ICTS is the caliber of the students. I had the opportunity to work with fantastic MSc students, as well as



With cleaning staff at ICTS. RUKMINI DEY

both short-term and long-term summer students from all over India. They came to do their master's projects or simply to spend some time at the institute, and it was wonderful. Now, I also have an excellent PhD student. That influx of student energy is definitely incredible.

Have your interactions with young students convinced you that there is much more scientific talent waiting to be nurtured?

RD: Absolutely. Outreach is never enough. We put in a lot of effort, but for outreach to truly work, it has to be sustained over a long period. You need to see the same students returning again and again, watching their interest grow until they eventually want to become scientists themselves. Scientific creativity is inherent in all children, but somehow, it often goes un-nurtured. That is why we need sustained, monthly activities. For example, we host astronomy talks and telescope viewing, and we bring in students from the surrounding villages. We see tremendous interest from them, but it cannot be just a one-time event. It is not enough to just say, "Oh, we looked through a telescope and saw Jupiter." It takes sustained effort to genuinely cultivate their interest in science—and when we do, we actually see it work.

"Scientific creativity is inherent in all children, but somehow, it often goes un-nurtured."

We organize many hands-on activities, and Professor Joseph Samuel and Professor Supurna Sinha have been incredibly active in this effort. The impact is profound; I have seen young girls say, "I want to be a scientist like you." Moments like that are incredibly special.

The Jawaharlal Nehru Planetarium (JNP) does a very good job of this, and we are actually considering adopting some of their methods. They have a program called REAP, which involves sustained effort to engage students over time. Ultimately, that program has produced excellent scientists, many of whom come from modest backgrounds.

If we are ever going to find the next Ramanujan, it will be through programs like this—sustained programs where students can return again and again for the mentorship they need.

What does a typical outreach event day look like? What activities are planned?

RD: There are various monthly events, of course. We have Math Circles that meet twice a month. Then there is *Kaapi With Kuriosity*, which is our regular monthly public lecture series. We host an Open Day. For an entire day, researchers from ICTS and other neighboring institutes come to showcase their experiments and work. Explain their research areas to anyone who visits, as the campus is completely open to the public. So, Open Days are a major undertaking. Then, there are also the PRISM events and many public lectures hosted. A list of our activities can be found in the outreach section of the ICTS website.

Can you think of a defining moment or a turning point in your career? How did it affect your outlook towards teaching, research, and life in general?

RD: I do not think it was a single moment; rather, it was the collective experience I have had with my students, from the long-term visiting and summer students to my current graduate students and postdocs. These were the real turning points. We have learned so much from one another, and it has been incredibly fruitful. The most important thing about youth is that they are not inhibited. As experienced researchers, we often hesitate because we fear saying the wrong thing. But students will freely voice their thoughts, whether they are perfectly correct or not, and that openness is invaluable.

It is truly amazing to watch them progress. I often say that my first graduate student, Pradip Kumar, changed my mathematical life. My entire perspective started shifting from that point onward. It began with my first student, then my second, and continued through all the postdocs, visiting students, and my current graduate student.

You seem to value that quality of asking questions, especially since young people are often afraid to do so. Why do you think it matters so much?

DEDICATED TO POSTDOCS AND
STUDENTS

*They came in with joyous energy, Happy to
learn and try the research into the unknown,
They went out, thoughtful young men and
women, Futuristic, optimistic and able.*

— Rukmini Dey
The Oriole in My Garden

RD: Students absolutely should speak up. Whether their ideas are right or wrong, that



Rukmini Dey and her postdoc at ICTS, Dr. Savita Rani

RUKMINI DEY

lem and paper, but he conducted his core PhD research entirely on his own. My greatest joy as a mentor is watching people take flight and soar far beyond me.

constant flow of innumerable ideas is what keeps science moving forward. If you are discouraged from asking questions, you are essentially discouraging your own mind from being creative. Because of this, I always gave my very good students freedom to pursue what interested them. For instance, with my first student, we collaborated on his very first prob-

Have there been any mathematicians or physicists whom you consider your heroes or heroines, people whose work or style feels especially close to your own?

RD: Yes, two women mathematicians in particular and I have already mentioned them: Professor Karen Uhlenbeck and Professor Dusa McDuff. I have always looked up to them for their profound reasoning and clear-sightedness. This has given me great courage and hope.

Finally, what role do music, poetry, and writing play in your life as a mathematician? Do they help you connect science with the broader human experience?

RD: Yes, absolutely. As I mentioned earlier, Tagore's songs are an essential part of my life. Whenever I have felt down, his music has never failed to lift my spirits and transport me to a different plane, one where I feel like sadness simply cannot reach me. Alongside singing his song, I have also been writing short vignettes and sketches from my own life, and I have actually published a few books of poetry. One of them is a recent book that brings together all my poetry. It's called *The Oriole in My Garden*⁵. Whenever I have a small idea, I note it down on my phone. To me, mathematics is the ultimate poetry. It is like a flowing stream, constantly moving and evolving, yet fundamentally still and clear. It is a philosophy in itself. Ultimately, poetry, music, and mathematics are all flowers from the same garden of freedom. That is precisely the concept I explored in my book. In the real world, you simply do not have the freedom to do whatever you like; we are bound by limitations. True freedom only exists within your own creativity. The major avenues where I have found absolute creative freedom are music, poetry, and mathematics.

"...poetry, music, and mathematics are all flowers from the same garden of freedom."

⁵The book is available on <https://amzn.in/d/oh3XNzvd>

TOWARDS THE HORIZON OF MEANING: INTERVIEW WITH PARTHA SARATHI CHAKRABORTY



Partha Sarathi Chakraborty at a restaurant. PARTHA SARATHI CHAKRABORTY

PARTHA SARATHI CHAKRABORTY is a mathematician at the Indian Statistical Institute (ISI), Kolkata. His research interests lie in operator algebras and noncommutative geometry. After completing his PhD under the supervision of Kalyan Bidhan Sinha at ISI Delhi, he held research positions at IHÉS and the Institute of Mathematical Sciences (IMSc), Chennai. In 2018, he joined ISI Kolkata as a Professor of Mathematics.

In this conversation with Saraswata Sensarma, Purnima Tiwari, and Aayush Verma for *Anveshanā*, Prof. Chakraborty reflects on his upbringing in Bengal, his early fascination with science, the meaning of doing mathematics, his approach to research and teaching, the influence of K. R. Parthasarathy's mentorship, and his journey through the different campuses of ISI—both as a mathematician and as an individual.

We are at this great institution for mathematics, speaking with a mathematician. So let us begin by asking: How has your understanding of mathematics evolved over the years, and what does it mean to you today?

Partha Sarathi Chakraborty: The meaning of mathematics for me has, of course, evolved with time; it had to.

As a kid, there was fun and a sense of power. You prove something, and then it becomes hard to refute. Nobody can challenge you, so it seems like the ultimate truth. There is a certain attraction to that. Then, of course, one experiences the fun of solving many problems, especially if one can solve them very quickly. It goes on for a while like that.

But then, as one grows, it evolves. When I entered the Indian Statistical Institute (ISI), there were many people, including some of my teachers, who have now retired, and who were very interested in mathematical logic. Under their influence, I also started studying logic, and then I realized that things are not really "true" in an absolute sense. That initial amazement diminished a little, but mathematics still remained immensely powerful.

Now, at the present juncture, when everybody is talking about AI and LLMs, there is a new task for mathematicians. Since all these depend on mathematics, we must point out its limitations. We must make it clear that proofs do not deliver absolute truth in the sense people often believe. We are essentially being taught not to question an algorithm's output, and that's a dangerous idea. While others may treat a proof as unquestionable, it is important to emphasize that we can—and should—question the output of an algorithm.



On a train. **PARTHA SARATHI CHAKRABORTY**

Additionally, one can now prove theorems using AI. Therefore, all of us should sit down and think: what does it mean to do mathematics? It is a very relevant question today. We see that almost every other day, one of Erdős' problems is being solved. There ought to be a collective discussion about what it means to say that we are doing mathematics.

Can you recall a mathematical problem, theorem, or idea that particularly fascinated you or changed the way you thought about mathematics?

"...proofs do not deliver absolute truth in the sense people often believe."

PSC: Even before my undergraduate studies, maybe in the 9th standard, I struggled quite a bit with a problem, though it was not very surprising. I still ask school kids this problem: consider a triangle, and then take the bisectors of the two angles at the base.

If they have the same length, then show that the triangle is isosceles.¹ Generally, other geometry

¹This is called the Steiner–Lehmus Theorem.

problems are very quick, but for this one, I really had to think for more than a month, which I enjoyed at the time.

At the undergraduate level, too, there was one surprising thing. In our first calculus class, our teacher wanted to define the natural numbers for us, so he said they are the "smallest" inductive set. Now, I got completely stuck, because the smallest among which collection? I searched a lot, and in those days, you did not have Google or the internet; you had to physically search for books in the library. I then learned that you can make this statement precise. I think Bernays, von Neumann, and Gödel, in their formulation of set theory, make a precise statement that the natural numbers are the smallest inductive set. This formulation is there in Dugundji's book. The statement was not really counterintuitive, because whatever inductive set you can think of, indeed, it looks like the natural numbers are the smallest, because you have to begin somewhere. Then you keep adding one, and you obtain the naturals. It was more about how to make the statement precise, and that requires a precise formulation of set theory.

Do you think mathematical maturity changes one's sense of what is obvious or counterintuitive?

PSC: Of course, as you pass to measure theory, various counterintuitive things start happening. But I do not remember anything off the top of my head. There are various theorems which are amazing, but I cannot say that they are counterintuitive. I think the sense that a theorem is obvious comes with extensive training and mathematical maturity. In general, things are not really obvious. For that, one has to become somewhat old and spend some time in an area; then you start seeing that some things are immediate.

And of course, counterintuitive things do come, but generally at a later stage. As you try to formulate a theory, maybe there are junctures where you do not have many examples to guide you through that development. It happens more in these quantum or non-commutative theories, where quite often you are guided by classical intuition. Now you ask yourself—what am I looking for? Am I looking for a problem or a development that parallels the classical development? Or something else that you do not see in the classical world?

If your intuition is guided too much by the classical world, then you do not find that really appealing. You may prove a result with a lot of hard work, but that is what you had expected to begin with. But say, even after hard work, you see that you are not getting what happens in the classical part, and you get something different; then it looks counterintuitive. I do not think it is a good idea to emulate the classical world too closely.

"If your intuition is guided too much by the classical world, then you do not find that really appealing."

Could you tell us a bit about your childhood and the environment you grew up in?

PSC: Just after my birth, we went to Jagdalpur and then moved to Shillong. I do have memories of Shillong, which was a very nice place, but none from my time in Jagdalpur. After a while in Shillong, however, we started experiencing political disturbances, so we moved to West Bengal. All of my early schooling happened in Bengal itself.

I would say that life in Bengal was very routine. At that time, it was very common for every child to do two things: study and learn to play some music. You would wake up in the morning, go to school, come back, and then practise music. Along with these activities, you had to study at a fixed time every day. I used to learn the sitar and practised it every day. It was a very rigid schedule, and there was no escaping it.

I vividly remember sitting with our books and studying even during Durga Puja. After studying, I would ask my mother if I could go pandal-hopping and participate in the festivities. So life was very routine, and having grown up like that, I still enjoy following a routine.

It seems that discipline and routine have remained an important part of your life.

PSC: Now that I wake up in the morning, I do certain things in a precise order, and it helps. I saw one of my professors, K.R. Parthasarathy (KRP), also following such a routine. But I



K. R. Parthasarathy in 1975.

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must admit that I cannot follow a routine like his. Before his lectures, even when he knew exactly what he was going to say, he would still write everything down meticulously and note every point to be made. He maintained all his notebooks very carefully. I do write, but I do not maintain notebooks in quite the same way as he did.

The last photograph of KRP is probably in that interview of Anveshanā with Raja-da [B.V. Rajarama Bhat].² At that time, he was almost blind. Even then, I think he was proofreading his last book. His wife used to read it to him, and he would make corrections. He maintained that routine even at that stage of his life. I find that very inspiring.

How did you first come to meet K.R. Parthasarathy, and what do you remember about that first meeting?

PSC: I met him in 1997, just as I joined my PhD at ISI Delhi. I vividly remember meeting him for the first time. At that time, the ISI PhD entrance

²A Life in Hilbert Space: Interview with B.V. Rajarama Bhat, *Anveshanā e-Magazine*, January 2025, available at: <https://anveshanamagazine.github.io/bv-rajarama-bhat.html>

examination was very different from most other PhD entrance examinations. They used to ask four or five questions. Each question was actually a theorem, and they would develop the result through a series of lemmas. Even solving two questions was considered very good, but each problem had five or six parts, sometimes even more.

I wrote both the ISI test and the TIFR entrance examination. I was really not sure whether to go abroad or stay in India, but by the final stage, I decided to stay in India.

Every day, I would come from my home to the institute and wait outside the Dean's office, where they used to publish the results on the notice board. I would check the board and then go home. If ISI had published its results, I would not have gone to TIFR. But ISI did not publish the results of its JRF written test until quite late, so I had to join TIFR.

One day, I met the Dean and asked him about the entrance test results. He said, "Oh, I was looking for you all over the place. You are the only student to have cleared the ISI test. Where would you like your interview to be held?"

"He maintained that routine even at that stage of his life."

I said, "Now it is too late because I have to go to TIFR the day after tomorrow. So I cannot have the interview right now." But after thinking for a bit, I requested that the

interview be conducted in Kolkata. The Dean said, "No, you have to go to Delhi because they wish to test you there." So I joined TIFR, and from there I went to Delhi for the interview. That was a very memorable experience. That interview was my first encounter with KRP, and I still remember his first question.

What was it?

PSC: "What is the meaning of Chakraborty?" I said, "Chakra means a circle—the king's circle—and it refers to the person who is present in that circle." KRP said, "No, no. The circle is incomplete without him. He is the king. Chakraborty means Raj Chakraborty."

I actually remember the entire interview. Then he asked, "Can you give me an example of a stochastic process?" All my teachers at ISI Kolkata had already taught me that whenever somebody asks you a question in an interview like this, you should begin at the most elementary level. So I started with the coin-tossing space, which I really like. Then he asked, "Do you consider the coin-tossing space to be the most important stochastic process?" I then had to talk about Brownian motion. After that, he asked something about Donsker's theorem that I still remember. Some questions were also from linear algebra.

More or less, that's it. That was my interview.

Is there any anecdote from the time when you were deciding between TIFR and ISI Delhi?

PSC: I will tell you one more story about my memorable trip from TIFR to ISI Delhi. I remember it quite vividly. One of my teachers, who is now the Director of ISI, was very excited and wanted me to join TIFR. He asked me, "Have you seen the Western Ghats?" I said, "Yes, I have seen the Western Ghats, but what is so great about them?" I did not quite realize his point at the time.

That night, on my way from Bombay to Delhi for my interview, Bombay experienced one of its torrential rains, and all the trains were either cancelled or delayed. At the station, they did not announce that my train had been cancelled. It was scheduled to leave at 5:00 p.m., and even at 7:00 p.m. they were still announcing that it was on time. I learned a funny rule: they could not utter a word without approval from the higher authorities.

Anyway, I stood on the platform throughout the night. Finally, around five in the morning, the train arrived. Everybody rushed in and quickly fell asleep. When I woke up five or six hours later, the train was standing at a station. To my surprise, it was still at Victoria Terminus! Eventually, the train started. Because of the rain, the entire Western Ghats looked serene. There were countless small streams flowing down the hills.

It was a very memorable journey. Looking back, I realize it was a wonderful experience. After all, you cannot really arrange a sight like that, with such heavy rain.

And do you remember the last time you met K. R. Parthasarathy?

PSC: I last met him, probably in 2016. That must be my last visit to ISI Delhi. After 2018, I have never really left Kolkata, even for a single night.

"I learned a funny rule: they could not utter a word without approval from the higher authorities."

Where have you been in your education, starting from undergraduate?

PSC: Just after my schooling, I entered ISI Kolkata. I did my B. Stat and M. Stat—everything here. Then, for my Ph.D., I joined ISI Delhi.

Before joining ISI Kolkata, did you always see yourself becoming a mathematician?

PSC: Yes, but that was not the plan. As a kid, I always wanted to study physics. In the VII or VIII standard, in physics books, you see the names of physicists, for example, Jagadish Bose and Meghnad Saha, and then you begin to learn about their lives. You generally do not really



Southwest Monsoon at TIFR. ANVESHANĀ

learn about their physics at that age, but you certainly learn about their lives, and there is a certain amount of romanticization. This made me want to pursue physics. But during higher secondary, I realized that physics practicals were quite difficult for me to perform. On the other hand, I also realized that mechanics problems attracted me more.

I always thought that I would study physics at Presidency College. And there was no doubt about it. Since everyone was writing joint entrance tests, I also thought I should write; otherwise, people would say I could not clear the test, and that is why I joined physics. I wrote joint entrance exams, including the medical school exam.

But one of my teachers happened to tell me, "If you like mathematics so much, why don't you write the ISI entrance exam?"



ISI Kolkata. ANVESHANĀ

The most exciting thing about the ISI entrance exam is that it tests only mathematics, not any other subjects. That was very interesting, but another interesting point was receiving a stipend while studying. I would not have joined ISI if there had been no stipend. Maybe I would have gone straight to the Presidency.

So that was when you decided to join the B.Stat program at ISI?

PSC: At that time, that was the only possibility. It was the best mathematics program in India. Moreover, TIFR was only hosting Ph.D. programs. While Integrated Ph.Ds were also available, very few people chose them, as they were not very popular back then. Indranil Biswas was one of our illustrious seniors. Even he did his M.Stat and then joined TIFR.

Let's rewind a little. How did your interest in science and mathematics first develop?

PSC: I think my father told me the following. In his time, the belief was that good students did not pursue engineering or medicine; instead, they studied in the general sciences and then went on to research. So, it was more or less decided. Besides, I do not think I was very good at languages such as Bengali and English. I thought that in science, one writes precise answers, not really essays, so this was probably why the sciences attracted me.

I liked mathematics from a very early stage. I remember some relatives were visiting us, and as people often do, one of them asked what my favourite subject was. My mother responded that she thought it was mathematics. I still remember that, from then on, I used to think, "If my mother thinks that mathematics is my favourite subject, then it must be so." I used to do all the problems from my elder sister's books, so it was quite clear that I would pursue

mathematics. At that time, most of the good students used to choose science. I now think good students should study philosophy, or at least reflect on philosophical questions. Of course, the sciences are somewhat important; one should really like to know how things work. It is a fundamental question. Physical realities surround us, and one cannot escape the attraction of questions about the natural laws governing their behaviour. Yet mathematics feels even more fundamental.

Mathematics allows you to deduce things without doing any experiments—just pure thought leads you somewhere. I mean, pure thought is really good enough for many purposes. When I first started reading books on probability, I imagined predicting the weather, and that would certainly be magical, right? At the time, that was what I thought probability was about. But once I entered ISI, I started doing very abstract mathematics and moved away from that connection with physical reality.

When you start doing mathematics in a very serious way, there is a risk of losing contact with real-life phenomena. It is probably a good idea to keep that connection intact, as it makes the subject more charming. For a while, I, too, felt that pure mathematics has its own attraction, dictated by logic. Through your attraction to logical ways of doing things, you become removed from natural or physical realities. But later on, you realize that perhaps one must reconnect with physical realities. Otherwise, it becomes a purely idealized setting. This is what I feel now.

“Mathematics allows you to deduce things without doing any experiments—just pure thought leads you somewhere.”

For example, while I was teaching complex analysis last semester, I thought I had to bring that connection into the course. The final problem I gave was on Kepler’s equation. I told the students that we are developing these concepts in complex analysis, which can be used to solve useful equations.

So, initially, I was attracted to physics but ended up immersed in mathematics. Eventually, I moved back towards physical realities. I think this second shift was influenced by people like KRP and my supervisor, Kalyan Bidhan Sinha [KB Sinha].

How did you eventually decide where to pursue your Ph.D., and what led you to choose ISI Delhi?

PSC: It was a very simple decision. After my master’s degree, I decided to pursue a Ph.D. At that time, I was essentially weighing two possibilities.

I did write the ISI entrance test, but I was not sure whether I would join. On the one hand, I was considering TIFR. It was regarded as the best place in India at the time. But there was another possibility that I was seriously considering—working in stochastic finance.

After my master’s, I met my one-year senior, Debashish Goswami, who was still at ISI Kolkata and had just begun working with B.V. Rao. During our conversation, he mentioned that he

was planning to change his supervisor, move to Delhi, and work with KB Sinha. He also spoke about the mathematical direction he intended to pursue, referring to the Atiyah–Singer Index Theorem and Bismut’s probabilistic proof, and suggested that I consider joining him in that direction.

He then mentioned that noncommutative geometry has index theorems, and that ISI Delhi had experts in quantum probability. The idea was to prove some of these noncommutative geometric index theorems using quantum probability.

He already knew that I was very interested in differential geometry. I had been studying it on my own since my second year of the B.Stat programme. He thought that I might be able to contribute to that programme. It looked like a golden opportunity. So I immediately decided to join ISI Delhi.



Kalyan Bidhan Sinha AMBARN SG THROUGH WIKIMEDIA COMMONS

Was that your first encounter with noncommutative geometry?

PSC: Yes. Before deciding to join ISI Delhi, I had never even heard of noncommutative geometry.

Because stochastic processes were very important at ISI Kolkata, all the time you heard about stochastic processes, Brownian motion, and stochastic integrals. People almost thought that was the entire world. Similarly, at that time, we used to think that this was the ultimate goal one could achieve.

What was it like to be a Ph.D. student ISI Delhi with KB Sinha and KR Parthasarathy?



From left: Debashish Goswami, Surya Jana, and Partha Sarathi Chakraborty PARTHA SARATHI CHAKRABORTY

PSC: Those years were some of the most memorable periods of my life. The environment at ISI Delhi was very friendly. There were very few Ph.D. students at ISI. In the year before me, only Debashish [Goswami] joined. In my year, only I joined. I believe that since there were so few of us, the teachers really celebrated the Ph.D. students. We would spend time together throughout the day. Every morning, I went to my shared office. It was all on the ground floor of the ISI Delhi building. It was I, Debashish,

KBS, KRP, and Arup-da [Arup Pal]—who was a postdoc there at the time, and he joined as a faculty member in June 1998. We would really spend the entire day together, right up until 5-6 in the evening. Our offices were right next to each other.

KRP would come to the Institute around 10 o'clock. He was very punctual about that, as I have already shared about his love for routine. And now and then, he would come into our

“One day, KRP would state a problem, the next morning, he would solve it, and then state another.”

office, go to the board, and state a problem. These sessions would happen between 10 and 11. Then, around 11 o'clock, all of us would go for tea together and discuss some

mathematics. One day, KRP would state a problem, the next morning, he would solve it, and then state another. It was very difficult to keep pace with him. Also, at that time, our interests were different. He was interested in quantum information theory, probably because his doctoral thesis was on information theory.

After working on other topics, like quantum probability, around 1997 or earlier, just after Rajada's thesis, I think he became interested in quantum information theory and cryptography. He became very interested in topics such as encryption and was constantly posing problems in that area.

On the other hand, at that age, you think that whatever you are doing is the greatest mathematics. Of course, we were interested in noncommutative geometry and were trying to read more about operator algebras. So, we could not really spend much time on his problems.

Anyway, we would come back to the office, and then all of us would go for lunch together at one o'clock. Debashish and I were talking throughout the day. In the hostel, two rooms shared a common bathroom. So, we were also bathroom mates.

Looking back, how do you feel about your decision to stay in India for your Ph.D.?

PSC: Not really. At that time, I was very confused about whether to go abroad, but I liked my mother's argument. She said, “Anyway, it is something you have to do. You have to write your thesis. Therefore, how should it matter so much whether you do it from India or you go abroad?”

I found this argument convincing. And as Amartya Da [Dutta] told me, if you go abroad, you have to manage your life—you have to cook your own food, and these things could be difficult. In India, you have a hostel where you get cooked food, and everything is taken care of. But in some sense, you get better exposure if you go abroad. However, there are advantages to being here as well.

“Every situation turns you into a unique individual.”

Meaning, a man is really forced by the situation he faces. Every situation turns you into a unique individual. So the situation could have been different if I had gone abroad. I might have pursued something very different. Stochastic finance is far removed from what I do. But on the other hand, the subjects that I pursued, I do consider magnificent. It connects several ideas from vastly different sources.

The idea of non-commutative geometry is an amazing one, and it is really by no means an obvious development. It is a highly sophisticated development. The theory is rooted in index theorems, so having a full appreciation of it is quite difficult, and I really enjoyed figuring it out.

Having spent time at both ISI Kolkata and ISI Delhi, what differences did you notice in the way mathematics was approached at the two institutes?

PSC: Actually, at institutes like ISI Kolkata and ISI Delhi, people think differently. I will give you a very simple example.

I did my master's at ISI Kolkata, and I remember a specific situation involving the two of us. Debashish did his second year at ISI Delhi and had his Ph.D. interview in Kolkata. I studied functional analysis during my master's at ISI Kolkata, and I had my interview at ISI Delhi. We both faced the same question in our interviews.

Debashish was asked what he knew about compact operators. He started answering by describing compact operators on a Hilbert space. And when I was asked the same question, I started answering by describing compact operators on a Banach space. This happened because at ISI Kolkata, under the influence of Professor A.K. Roy, the emphasis was heavily on Banach spaces. There, you start with Hilbert spaces, and then you prove that a Hilbert space has a unique invariant, namely the cardinality of its orthonormal basis. I don't think it was explicit, but the implicit message I got was that the theory of Hilbert spaces is over. Let us move to Banach spaces.

On the other hand, when you go to ISI Delhi, they are interested in operators on Hilbert spaces, and they say that a Hilbert space has a life of its own. Any two infinite-dimensional separable Hilbert spaces are unitarily equivalent, but they are not quite the same. For example, $L^2(\mathbb{R})$ and $L^2(\mathbb{Z})$ are not really the same thing.



Partha Sarathi Chakraborty, Surya Jana, K.V.S. Vinay, and Sourav Mukhopadhyay (M.Stat Students) in front of the statue of PC Mahalanobis. **PARTHA SARATHI CHAKRABORTY**

That was a major change in our attitude. At ISI Kolkata, the emphasis was on what I would call pure mathematics. The moment one went to ISI Delhi, one became a member of what KRP used to call the quantum group. So, there was a clear-cut transition in how we were doing mathematics.

But what do you mean by transition in the style of doing mathematics?

PSC: Now again there is another question—what did we mean by doing mathematics? At ISI Kolkata, people were concerned about very abstract mathematical questions. For example, consider the Borel isomorphism theorem. You take two sets and ask whether they are Borel isomorphic, and you learn about such things. These questions felt completely removed from reality, or at least that was how it appeared to me at the time. One should not take that past judgment too seriously now, but back then it was posed to us as a purely mathematical question, with no connection to physical realities.

On the other hand, the moment you went to ISI Delhi and talked to people like KRP or KBS, they immediately started connecting things.

Do you recall such an interaction?

PSC: I remember a shocking discussion with my supervisor. Debashish and I were both sitting in front of him, and he [KBS] asked us, "Do you know Newton's laws?" We said yes.



Then he replied, "Do you know Newton's third law?" We said yes, of course. He asked us to give some examples. Naturally, we told him about how we were standing on the ground and so forth. Then he asked us to imagine the following scenario. Think of the frame of a table, but instead of a solid wooden board on top, we put a piece of paper and ask you to stand on it. Now, "If Newton's third law is valid, then what will actually happen? Of course, the paper will fall apart, right? It will tear, and you will fall through."

With KB Sinha in front of a café.

CHAKRABORTY

PARTHA SARATHI

He explained that the first and second laws are about force. They provide a qualitative definition of force, followed by a quantitative expression. But the third law is, in fact, the qualitative definition of a rigid body. But of course, rigid-body motion is much more difficult to calculate. And this is what our interactions with them were like.

"It was a massive transition in how I viewed mathematics."

Since they understood physics so deeply, they would connect abstract mathematics to real physical systems from time to time. That

level of mentorship led to a major change in my attitude. It was a massive transition in how I viewed mathematics.

How close were they to mainstream physics?

PSC: I am not quite so sure about that. Of course, they were interacting with many mathematical physicists, but you realize that mathematical physics is not quite physics, right?

But I am not sure about their interactions with experimental physicists, but I am sure they were in touch with theoretical physicists, particularly those from Europe.

Did ISI have active theoretical physicists at that time?

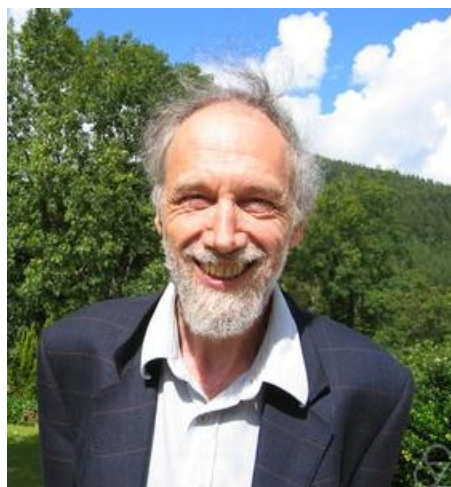
PSC: No. ISI does have a physics department, but I do not know about theoretical physicists. I did take electives in physics, but it was not really that appealing.

ISI Delhi did not have a physics department. ISI Kolkata did have one, but I think the main difficulty was language. See, the mathematicians are too keen on such things. For example, when you meet my supervisor, he will say that self-adjointness is a big issue. If you are a mathematician, indeed, self-adjointness is a big issue. Symmetric operators and self-adjoint operators are not quite the same thing. And, physicists do not make those distinctions all the time. Physicists are not really bothered about these mathematical issues all the time. Of course, they had some connection with physics, but at the end of the day, both KRP and KBS are really mathematicians.

What was your first exposure to non-commutative geometry like, and which aspects of the subject impressed you most initially?

PSC: At the time I started reading the subject, there were not many books. As I joined ISI, the first paper I was asked to read was [Alain] Connes' IHES paper. That, I think, must be his first paper on the topic. I believe so. It could be a controversial statement, but I believe it must be so, because that's where he is talking about the program, right?

The paper³ is titled "*Non-Commutative Differential Geometry*." There, he discusses the program and introduces fundamental concepts such as cyclic cohomology. He demonstrates his new subject by



Alain Connes at Oberwolfach in 2004.
DISCOSTU THROUGH WIKIMEDIA COMMONS

³Connes, Alain. "Non-commutative differential geometry." Publications Mathématiques de l'IHES 62 (1985): 41-144.

giving a beautiful solution to the no idempotent conjecture for free groups on two generators. The conjecture was the following. You consider a free group on two generators, and then in its group ring, he proves that there are no non-trivial idempotents. As you state this problem, it looks purely group-theoretic, because you have a group that fits into a general conjecture. The conjecture is the following. If a group has no torsion elements, then its group ring has no non-trivial idempotents. And apparently, as you look at this problem, you do not see any connection to any geometric ideas. But it is amazing how he makes all those connections and proves it.

And even yesterday, I was trying to convince students about the greatness of the subject by telling them about his [Connes'] argument. Of course, this conjecture was open for about 20 years, and it was settled by Pimsner and Voiculescu. Connes also gave his absolutely cute argument. And then, in that article, he talked about his program, which aimed to answer some very interesting questions. And so the subject looked really very inspiring, I would say.

Would you describe non-commutative geometry as a generalization of classical geometry, or as a fundamentally different viewpoint?

PSC: It is a very different way of looking at things, and is not at all a trivial generalization. The idea that you can capture spaces by cycles in some suitable homology theory is not very uncommon. In algebraic geometry, they study cycles. But the fact that you can encode very fine differential geometric ideas through some very specific cycles is not at all obvious.

"It is a very different way of looking at things, and is not at all a trivial generalization."

Connes, I think, wrote his book around 92-94. There, he mentioned a reconstruction theorem for classical spaces. The proof to him was clear, as many things could be, but he did not really bother to write them down. At the same time, other people were trying to prove it.

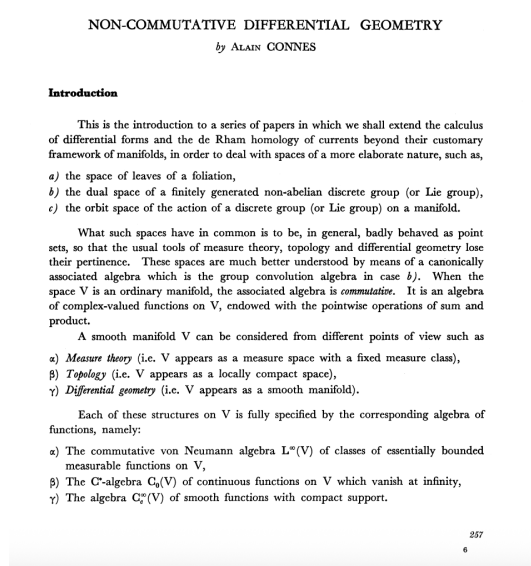
Connes' remarks must still be publicly available, noting that someone has attempted it, that there are mistakes to be corrected, and so on. So eventually he wrote down his proof. His proof of the reconstruction theorem was published around 2012. It is a highly non-trivial idea that you can encode all the information of a Riemannian manifold, or a compact Riemannian spin manifold, into some sort of functional analytic data.

The framework of noncommutative geometry brings together analytical, algebraic, and geometric structures.

PSC: : Yes, all these ideas are kind of coupled in a rather fine way; to a certain extent, it is a mixture of analytical and algebraic ideas. Because you have a self-adjoint Dirac-type operator with compact resolvent, you have an algebra. Now, you start making very strong demands on them, and they are also algebraic in a certain sense, and they produce certain modules which are subsets of a Hilbert space, which are finitely generated, projective, etc.

How should one understand the relationship between the C*-algebraic formulation and the spectral triple framework in non-commutative geometry?

PSC: I do not think that there is any difference between the two approaches. A commutative unital C-star algebra is really a space of functions on a compact Hausdorff space. If you remove the commutativity, you have the analogs of non-commutative spaces.



Facsimile of the first page of Connes' famous 1985
IHÉS paper [IHÉS](#)

But what does it mean to say "doing geometry"? Look at what algebraic geometers do — they study cycles. That means, doing geometry should amount to studying some cycles. That idea was known. Even Atiyah had posed this problem; he called these things "abstract elliptic operators," but he did not quite describe the equivalence relation that turned it into a homology theory. Kasparov did that. Connes then realized that considering unbounded cycles could capture even finer information.

Another key point is the pairing between cycles and K-theory. It was already known since the 70s that K-theory could be done in the framework of Banach algebras. Karoubi wrote his book, K-Theory for Banach Algebras, in the 70s. The pairing between K-homology and K-theory was also known from Kasparov's work.

Connes's remarkable construction was cyclic cohomology, in which he introduced the Chern character and the pairing, and this was the connection to the spectral triple. The spectral triple is really an element in K-homology, but with finer properties. Not any cycle will do, and not all cycles carry the same amount of information. There are certain good cycles, and then using them, you can construct certain meaningful things.

Then you ask: can you really encode all the information in a few very good cycles? That was his [Connes] reconstruction theorem. Spectral triples are therefore not far removed from C*-algebras. If you have a C*-algebra, you have its K-theory and K-homology groups, and elements of K-homology groups are the spectral triples. Certain spectral triples contain more information, and those are the candidates for non-commutative geometric spaces.

Non-commutative geometry was also motivated by ideas from quantum mechanics and particle physics.

PSC: Connes did something remarkable about which he was very excited. He derived the standard model from his Yang-Mills action and presented a rather conceptual derivation as an optimization principle, or a least-action principle.

It has also influenced areas such as string theory and condensed matter physics.

PSC: It has its reach among physicists. Maybe not that much right now. But it is a convincing argument, more or less, to many people.

Have you met Connes?

PSC: Yes, I have when I was visiting IHES for longer durations.

“But what does it mean to say ‘doing geometry’?”

During your Ph.D., your work focused on quantum probability and aspects of noncommutative geometry. Could you describe the main directions you worked on at that time?

PSC We started with that, and my first paper was on the topic. I think it was published in the Journal of Operator Theory.⁴ In quantum probability, one starts with a semigroup of completely positive maps and dilates it into a flow of homomorphisms. We constructed a CP semigroup on the noncommutative torus and dilated it. We also studied perturbations of spectral triples, though we were not yet very familiar with the homological background. We proved that the perturbation is not unitarily equivalent to the original, though later one realizes that unitary equivalence is not the right equivalence relation.

After some work on an equivariant version of a problem in quantum probability, I did not pursue the subject much further because its framework did not seem compatible with noncommutative geometry. I could not see any connection with these cycles. Although Jean-Luc Sauvageot and Cipriani later produced something, the two areas largely lived their own lives. There was nothing like Bismut’s work connecting them.

What did you explore mostly?

PSC: So I explored two questions: the quantum Heisenberg manifold, which I liked a lot, and embedding quantum groups into noncommutative geometry. At the time, the prevailing belief was that quantum groups were not compatible with the framework, and there was

“We thought that if we tried hard enough, we might prove something.”

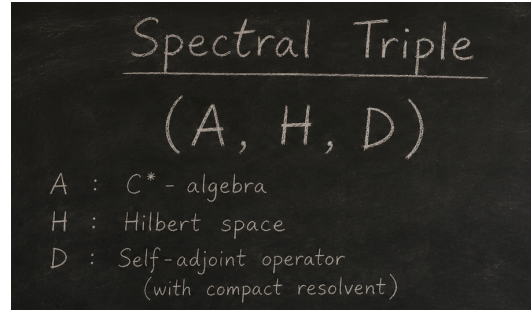
correspondence suggesting that it might need to be modified. Arup Pal—whom I refer to as Arup Da—and I disagreed. There was no proof of incompatibility; only some obvious guesses had failed. We thought that

if we tried hard enough, we might prove something. And we did—we proved that quantum $SU(2)$ admits spectral triples.

Of course, there are further technicalities. One asks whether a spectral triple is finitely summable. This is an analytic property that abstract homology does not provide. We

⁴Chakraborty, P. S., Goswami, D., Sinha, K. B. (2003). Probability and geometry on some noncommutative manifolds. Journal of Operator Theory, 185–201.

constructed a finitely summable spectral triple representing a non-trivial K-homology class. We submitted the paper to K-Theory⁵, and I believe Alain Connes was the referee. Our argument was rather intricate. Connes observed that the required properties of the operator could be verified directly and confirmed that it was indeed a non-trivial spectral triple.



At the time, he was interested in illustrating the local index formula he had proved with Moscovici in 1997. To apply it, one needs spectral triples satisfying regularity and possessing a finite-dimensional dimension spectrum. Connes proved that our spectral triple had these properties, computed its local index formula, and made some remarkable discoveries. For instance, the Dedekind eta function appears as a coboundary given by the difference between two cocycles representing the same class. Why this happens is still not entirely clear, and probably a more general framework is needed to explain it.

A set of data is a *spectral triple* with some *properties* satisfied. ANVESHANĀ USING CHATGPT

After that work, it became clear that quantum groups can produce finitely summable spectral triples, particularly under equivariance. Neshveyev and Tuset later constructed such spectral triples for $SU_q(N)$ and general compact quantum groups, but I do not think their regularity has been verified. Computing the dimension spectrum and the local index formula in that setting remains open. That work may eventually explain the appearance of the Dedekind eta function in this computation.

How should one evaluate a large mathematical program, such as non-commutative geometry or the Langlands program? What, in your view, constitutes success in such a program?

“Our task, then, is to recognize structures and to develop the language to describe them.”

PSC: I think that new definitions and examples are important, especially today. It makes me wonder: what is the purpose of a mathematician in the near future? As kids, we enjoyed solving geometry problems by look-

ing at a picture and connecting the dots in our minds. Now, there may be assistants capable of making such deductions. If so, perhaps our role lies elsewhere.

Our task, then, is to recognize structures and to develop the language to describe them. There are many highly non-trivial structures, both abstract and arising from the real world, that

⁵Pal A, Chakraborty P. Equivariant Spectral Triples on the Quantum $SU(2)$ Group *K-Theory*. 2003;28(2):107-126.

remain to be understood. The nature of mathematics will become much more complex, and perhaps we are now in a position to address it. Earlier, for instance, children spent time memorizing multiplication tables. I am not sure whether children today still memorize them. If they still do, I do not quite see why, given that we now have very effective tools for such tasks.

In doing mathematics, we will likely have very powerful machines at our disposal. What we will need, therefore, is the right language. Languages emerge from examples and develop to describe structures. Formulating the appropriate language is not easy, and it may well be the central challenge. At present, we prove propositions and develop our own understanding of structures. In the future, we will likely have powerful assistance in doing so. However, I do not think machines will be able to formulate the language itself. They may be effective at problem-solving, but building a theory is a different task. It is not entirely a question of theory-building versus problem-solving, though there is some overlap. Theory-building is about finding the right language, and its formulation will remain essential. I remember

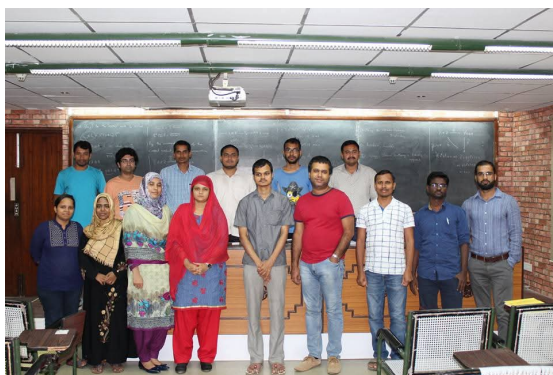
Vaughan Jones saying, “Location, location, location, that’s the key consideration, as far as property is concerned. Location is the first word and the last word.” He would then say, in mathematics, “Notation, notation, notation,” and that “notation is the first word and the last word.” That conveys how fundamental language and notation are in mathematics. He was speaking about planar algebras, where the notation is indeed remarkable.

Oh, have you met Jones?

PSC: : Yes, I met him.

He was a wonderful barista as well.

PSC: Indeed, he came to IMSc—more than once. He also visited when I was a faculty member there.



At a summer school at IMSc organized by Partha Sarathi Chakraborty. **PARTHA SARATHI CHAKRABORTY**

On that, you joined IMSc. How did that transition happen, and what drew you to Chennai?

PSC: IMSc was very nice. I had never imagined that I would go to Chennai for a job; it was not something I had really considered.

When you grow up in India, you tend to think of TIFR as the ultimate destination. So, when I was applying for jobs, I applied to TIFR and to ISI. Then I met V. S. Sunder, who asked me, “Why did you not apply to IMSc as well?”

Then I applied to IMSc, and they made a very attractive offer. I decided to join, and it turned out to be an excellent decision. One of its strengths is that it is an extremely friendly and relatively small institute. Everyone knows everyone else, and there is a very friendly atmosphere throughout the institute.

Was this your first employment after your PhD?

PSC: Well, it was my first permanent position. After completing my PhD, I went to the UK for a postdoctoral fellowship funded by the Royal Commission for the Exhibition of 1851 at the University of Cardiff. I was originally supposed to go to Paris for my first postdoc. However, some complications arose regarding the transfer of funds, including a bureaucratic delay. From Cardiff, I moved to IHÉS for an extended visit. I completed my postdoc in 2005 and then came to ISI Delhi for a short visit of about six months. After that, I joined IMSc.



In front of a train. **PARTHA SARATHI CHAKRABORTY**

IMSc also has a very lively physics department.

PSC: In fact, IMSc had some very interesting traditions. One of them was called the Institute Seminar Week. Every year, people from different disciplines give a 20-minute talk. In twenty minutes, of course, you cannot say very much. The idea was not to go into technical details, but to tell colleagues from other areas what you were working on and why it was interesting. I thought that was a wonderful idea.

At ISI, I have often told my colleagues that we should have something similar. Unfortunately, I have not been able to make it happen. Perhaps I have not done a good enough job of convincing them of its value.

I think such initiatives help people understand the basic ideas and problems that their friends and colleagues are thinking about. We should make an effort to communicate. After all, if we cannot communicate effectively with fellow scientists, how can we expect to communicate

“...if we cannot communicate effectively with fellow scientists, how can we expect to communicate with the broader public, with bureaucrats, or with anyone else?”

with the broader public, with bureaucrats, or with anyone else? We should be able to explain what we are thinking about, why it matters, and its significance.

What was your experience at IHÉS like? Did you interact with Konstevich and other people?

PSC: Yes, of course. IHÉS is a truly wonderful place. Anyone who spends time there tends to enjoy the experience immensely. My first visit lasted six months; I returned later on two more occasions. It is an environment where everything is conducive to good work—you have excellent food, excellent company, and a vibrant intellectual atmosphere. What more could one ask for?

What led you to decide to move back to ISI Kolkata after your time at IMSc?

PSC: In 2018, after spending twelve years at IMSc, I moved to ISI Kolkata. I had a wonderful experience at IMSc. I thoroughly enjoyed my time at IMSc, but as my parents were getting older, I decided to move to ISI Kolkata.

Do you think there is increasing fragmentation within mathematics, even between different subfields?

PSC: Yes, there is. This is not a particularly new idea. You may recall Gian-Carlo Rota’s article⁶, “Ten Lessons I Wish I Had Been Taught.” One of his suggestions was that a mathematician should write the same paper several times, each version aimed at a different audience and level of accessibility. I think there is a great deal of wisdom in that advice.

I do believe that communicating ideas is an important responsibility of scientists and mathematicians — whether to students, to the general public, or to colleagues in other disciplines.

For example, consider a recent case where a computer program solved a longstanding problem in geometry involving distances. What was striking was not only the solution itself, but also the way it drew upon ideas from several different areas of mathematics. It concerned the Erdős distinct distances problem and involved techniques connected to algebraic number theory. Developments like these show how deeply interconnected mathematical fields can be. Precisely because of these connections, we must explain our work beyond our immediate area of specialization. Otherwise, many interesting ideas and insights remain inaccessible even to other scientists.

“What seems obvious or elementary to you may be quite non-trivial and illuminating to someone else.”

When someone is invited to give a talk, they often feel they should present the most sophisticated result in their area. The result may be impressive, but conveying its significance to people outside the field can be difficult.

Sometimes it may make more sense to discuss something that appears trivial to you. What seems obvious or elementary to you may be quite non-trivial and illuminating to someone else. The same applies in the other direction as well.

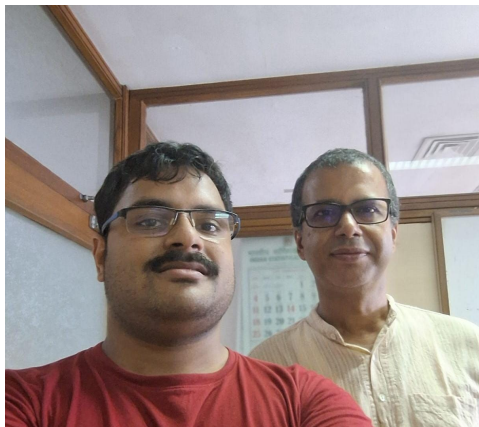
In a sense, this is part of what it means to do mathematics today. Mathematics is not only about discovering new results; it is also about communicating ideas, building connections,

⁶Available at <https://www.ams.org/notices/199701/comm-rota.pdf>

and helping others understand why certain questions matter. I think that is certainly one of the responsibilities we should take seriously.

What does “mathematical maturity” mean to you, especially in the context of training future researchers?

PSC: Well, this has to be judged differently in different cases. I cannot give you a single formula for assessing mathematical maturity, because we do this all the time, and it depends heavily



Partha Sarathi Chakraborty with his student
Saraswata Sensarma *ANVESHANĀ*

on the individual student and their background. In fact, I would distinguish mathematical maturity from aptitude. When someone solves a combinatorics problem quickly, for example, that may reflect aptitude, but not necessarily mathematical maturity. Maturity is more closely related to one's background, preparation, and understanding of mathematics.

So, when we talk about mathematical maturity, we have to take into account the person's prior training. Given a student's background, one develops certain expectations about what they should know and how they should think about mathematics. After an undergraduate program, one would expect a reasonable degree of familiarity with a few fundamental subjects. In particular, I mention three broad areas: linear algebra, calculus, and some basic algebra. That would be a natural expectation.

How should a young mathematician approach the choice of research problems that deserve a lifetime of thought?

PSC: On this question, different people have different thoughts. I think TIFR popularizes this idea. There, as one joins a PhD program, one goes through very serious training for one year. And probably they do that because they expect every mature mathematician to know certain results. So, that is not a bad idea. What that does is allow more serious communication across diverse areas of mathematics.

A mathematical researcher should have a good idea of a reasonable introduction to algebraic topology, a good introduction to measure theory and functional analysis, and some reasonable algebra and commutative

algebra. Non-commutative algebra is not that common, but differential geometry, some Lie groups, and Lie algebras, for example, are things everybody should know to a certain degree.

“But sooner or later, one has to choose a problem wisely. This is a difficult decision.”

To become a mathematical researcher, you should have a basic understanding of many of these topics. But sooner or later, one has to choose a problem wisely. This is a difficult decision. Why?

Because, from my experience, more often than not, choosing a problem is really an emotional decision. For most people, it is. Atiyah has done that, and he is a Fields medalist. To understand the problem, one already has to invest a good amount of time in that area. If one is interested in problems on the frontier, one really has to dig deeper into an area. So one has to invest a year or so, or more. And then it is not easy to change from one frontier to another. Therefore, one already has to make some sort of emotional decision. Of course, nowadays there are various other ways to decide.

I no longer suggest that my students choose problems the way I did; I simply rule that out. When we were students, even reading a mathematical review was difficult because we had them in hard copy. Mathematical Reviews (AMS) used to be some big, fat, orange-colored books where one physically browsed through reviews. These days, with a click of a button, one can see who has referred to a paper, what kind of work is happening, in which journals it is appearing, and so on. A much more mature decision is possible now. It was not possible when we were students, but now one can check what kind of work is happening in these areas.



With Rishiraj Baul and Satwata Hans. **PARTHA SARATHI CHAKRABORTY**

I am suggesting that probability is the key area in which it makes sense to invest. And I am telling all my students, invest in probability. But then, I have to justify it to them. If you check the schedule of talk⁷ at ICM, you can figure out why one should invest in probability, and now you can make a mature decision.

“A much more mature decision is possible now.”

These days, we have access to information, and analyzing it is much easier. Therefore, one can make a mature decision today in that sense. And probably one should do that. But there are risks too. For example, nobody will think about doing something that is fundamentally

⁷There are 10 talks in ‘12-Probability’ section of ICM list at <https://www.icm2026.org/event/ac193975-5d24-4628-8c30-ddb23de19a8b/speakers>.

different from what is happening and is rather far removed from the center of activities. Those possibilities are somewhat reduced. But I'm sure there will be people sitting in some corner trying to do all sorts of things. That possibility is now with established researchers. But these days, even aging people come up with interesting results. But people still think that mathematics is a game for young minds. For being a very serious mathematician, one has to really learn a lot, and therefore should not take that comment very seriously.

Has your approach to suggesting problems to students evolved over time, or have your expectations about when a student is ready to tackle a problem remained the same?

PSC: Not very much. There are certain minimal requirements: the student must be familiar with certain topics, and then they can tackle a problem. So I do not think that view has changed. The requirements I would have considered sufficient for tackling a problem then are more or less sufficient even today.

Do you still engage with music, or has it remained mainly a part of your earlier years?

PSC: I learned how to play sitar for a while. Around the 11th or 12th standard, I realised the sitar is a very big instrument⁸, and you cannot really move around with it. Therefore, that was not a good idea, and I ended up discontinuing. During my PhD, I had some time, so I started learning the flute. A flute is an easy-to-carry instrument, and it may not be as magnificent as a sitar, but it is still an interesting instrument. So in my free time, I enjoy playing the bamboo flute.



As a child playing Sitar at the annual program in school. **PARTHA SARATHI CHAKRABORTY**

Do you read? If yes, how do you find which books to read or not?

PSC: I enjoy reading. These days, books are also very easily available, and once you start reading, agents are exploring your mind, and you should let them explore. I should not resist. You should let them explore, and these agents, at times, I would say, make good suggestions. For example, Facebook does that. For instance, it suggested that Princeton University Press has a Facebook page. You can check that page and learn about their latest publications, and they promote books that are of interest to you. So that means some machine in some corner has figured out your mind. That is perfectly all right,

What kind of literature and books do you read?

PSC: There are various kinds of books, but there are certain philosophers whom I cannot deny. I think there is an underlying philosophy in our reactions. We may not make it explicit, and we may not even realize it, but every human life reflects philosophical thoughts about life itself.

⁸The average Ravi Shankar-style sitar measures about 48 to 51 inches in length and weighs roughly 3 to 4 kg.

In the academic profession, we have certain luxuries: some free time to think. At such times, one learns what others are thinking. Given any issue, one can ask philosophical questions — about the nature of life, the meaning of human life. These are philosophical questions, though we now approach them with very different methods. Large language models, for example, allow one to ask whether life has any meaning.

For example, consider the DNA sequences of living creatures. Perhaps these are all expressions in some language. Is this language evolving in some sense? How is it evolving? These questions have become relevant. Can the large language models be employed to understand the evolution of these DNA sequences? Will that shed new light on the meaning of life itself?

“The ultimate realization is not expressible in language.”

This leads to Wittgenstein’s question: are there things beyond language? The last proposition of the Tractatus says, “Whereof one cannot speak, thereof one must be

silent.” Here precisely, he is hinting about things beyond the reach of languages. We are now seriously exploring language, perhaps for the first time at this scale. What does it mean for something to lie beyond language? Are there things not expressible through language?

This resonates with certain spiritual ideas. For example, one cannot speak of Brahman in language; it is an experience. Ramakrishna Paramahansa gives the example of sugar: whatever you say about it, you cannot explain it unless one tastes it. The ultimate realization is not expressible in language.

Living a life in math, what do you think a mathematician can learn from people who devote themselves to other vocations other than math and academia in general?

PSC: Let us begin by asking: what did von Neumann think when [Oskar] Morgenstern approached him? He thought about game theory and human behavior. When a mathematician thought about human behavior, he formulated game theory—a mathematical way of approaching it. This is a fundamental lesson: whenever we observe something happening elsewhere, a mathematician translates it into a precise language. This connects with the earlier point about devising the correct language.

Mathematicians should interact with people from other areas and assist in formulating the appropriate language. In this way, one obtains many new problems. Once problems are formulated mathematically, their analysis can be assisted by machines, enabling deeper mathematical exploration of the world. So far, many of the problems we have tackled involve simplifying assumptions and removing ourselves from real life. We can now address more complex structures through an appropriate mathematical language.

If a machine can speak as I do, then the language I am using is not very complex. Then one can move towards more complex problems by translating them into a precise linguistic framework. At some point, such languages may go beyond our unaided capabilities. However, with the

assistance of machines, we should still be able to understand them to some extent.

An example of a complex structure is soil. Gromov, in one of his lectures, remarked that we do not know how to treat soil mathematically. A mathematician does not know how to describe it. This reflects the absence of an appropriate language. One has to develop such a language. So, mathematicians should interact with people from other fields, understand their problems, and translate them into mathematical language, much like von Neumann did.

“If a machine can speak as I do, then the language I am using is not very complex.”

A HOME CALLED THE LIBRARY: INTERVIEW WITH K.K. SURESH KUMAR



A potrait of K.K. Suresh Kumar K.K. SURESH KUMAR

K. K. SURESH KUMAR is the Librarian at Harish-Chandra Research Institute (HRI), Prayagraj. Born into the Kodava community of Karnataka, he discovered a love for books at an early age, a passion that led him to pursue Library and Information Science at Kuvempu University, Karnataka. Before joining HRI in December 2017, he served at the Indian Institute of Management Bangalore (IIM-B), ESSAE–TAPMI Academy, Bangalore, and the Amrita Vishwa Vidyapeetham University Bangalore campus, where he contributed to the development of modern academic library services.

In this interview with *Anveshanā*, Dr. Suresh Kumar reflects on his childhood in Chikkamagalore District, the mentors and family who shaped his journey, his philosophy of service, the evolving role of libraries in the digital age, and his enduring commitment to open access and making knowledge accessible to all.

Let us begin with your background. Could you tell us about your family?

Suresh Kumar: I am from Kodagu District (Coorg) in the state of Karnataka. We are the Kodava community—the native inhabitants. Our parents had three children: my elder sister,

my elder brother, and me. My father worked as a division head at one of the well-known coffee and tea estates (Kelagur Coffee and Tea Estate) in the Chikmagalur district of Karnataka, while my mother was a homemaker. I belong to the Kodava community, and my family name is Karthura.

Please introduce our readers to the Kodava community and its distinctive cultural traditions.

SK: We belong to the Kodava community of Kodagu (Coorg).¹ The district lies in the Western Ghats of Karnataka. The first mention of the Kodavas was in the Palpare inscription from Nallur village in South Kodagu, published in the Imperial Gazetteer of India in 1908. We are also known as *Coorgis*, and Coorgi families can range anywhere from 100 to around 500 members. Traditionally, we are a warrior-heritage society, known for ancestor and nature worship and strong martial traditions.

We organize ourselves into okkas (clans). There are over 1,000 to 2,000 distinct Kodava family names (okkas), each traditionally associated with an ancestral home called an *ainmane*, which serves as the centre for family gatherings. These patrilineal clans are the primary identity of Kodava individuals.

Our culture is a tribal one. We do not marry within the same clan, and Kodava marriage ceremonies are completely different from marriages anywhere else in India. Our traditional jewelry, music, and wedding dances are also unique. The Kodava community does not practice the dowry system.



Suresh Kumar's marriage in the tradition of Kodava culture. **K.K. SURESH KUMAR**

Actually, the Kaveri Purana [or Cauveri Purana], the oldest literature pertaining to the family deity of the Kodavas, viz., Kaveri, and the origin of the river Kaveri (also known as South India's Ganga), narrates that the Kodavas are descendants of King Chandraverma of the Kadamba dynasty, who ruled over Kodagu from the fourth century to the middle of the sixth century. It further narrates that when their family deity, Kaveri, transformed herself into the holy river, the Kodavas of the land were already in good number, and she blessed and assured them of her protective grace. Thus, according to the Kaveri Purana, the Kodavas predate the mythological manifestation of the river Kaveri.

¹The name "Kodagu" comes from the native Kodava language word Koda, meaning "hills" or "dense forest". During the colonial era, the British found the rolled consonants of the original name difficult to pronounce, leading to the Anglicized version, "Coorg". A more complete description of the Kodava community can be found at <https://www.kodavasamajabangalore.org>.

Is there any specific music or sport that the Kodava community enjoys?

SK: Yes, there is a specific music followed by the Kodava community. The key types of Kodava folk songs are Mangala Paat (weddings and joyful celebrations), Baalo Paat (narrative songs), Polachi Paat (harvest songs), and Chaavu Paat (mourning or memorial songs). Traditional music is accompanied by Valaga and dance rhythms.

This passion for hockey continues through the annual Kodava Family Hockey Tournament. In 2025, a record 451 Kodava families participated. The tournament is regarded as one of the largest field hockey tournaments in the world and has been recognised by both the Limca Book of Records and the Guinness World Records. Besides hockey, the Kodava community has also produced star players such as Rohan Bopanna (tennis) and Ashwini Ponnappa (badminton).

How was your childhood, and how did your early and higher education shape your interest in books and, eventually, librarianship?

SK: My childhood began at the beautiful Kelagur Coffee and Tea Estate in the Chikmagalur district. It is a massive, 800-plus-acre estate split into three divisions, and my father was the divisional head of one of them. Those early years were wonderful; they were truly interesting



Suresh Kumar [far left] and the family at Kelagur Coffee and Tea Estate in his childhood (1975).

K.K. SURESH KUMAR

and full of adventure. I vividly remember my parents keeping the Ramayana and Mahabharata for us. This was roughly between 1977 and 1982. My father would also bring home the Vikrama weekly and the Udayavani newspaper.

about 3 kilometers from the Kelagur estate. We used to walk there every day, and in those days, the teaching standards were genuinely good, even in government schools.

As a child, I had no idea about librarianship, but I was very interested in reading from a young age, especially comics, newspapers, and storybooks. I was a good student with natural leadership qualities, and I studied at GHPS (Government Higher Primary School), Javali, a government school

In my 6th standard, to support my elder sister's and brother's education, my father shifted our family to Chikmagalur city. I spent only a year there, but reading had a profound influence on me. That was another turning point in my life. I studied at Vishwavidya Nilaya Primary School in Kote, Chikmagalur. Near the school, on the way, was the District Central Library in Kote, and I was naturally drawn to it. During that time, I started reading newspapers, biographies, novels—especially adventure and detective novels—and visited the library even on Sundays. I vividly remember my parents sometimes scolding me for coming home late in the evenings. Comic books were also very popular then, and my neighbours and I would exchange and read them together.

Due to my father's illness, we returned to the estate, and I continued my education at GHPS, Javali. But after my father's sudden demise, everything was turned upside down. In October 1983, we moved to the small village of Gonibeedu in the Shimoga district (near Chikmagalur), where my father's brother was employed at the Bhadra Reservoir Project [B.R. Project] on the Bhadra River.



Suresh Kumar's father (in front-left without cap) with estate owner. **K.K. SURESH KUMAR**

In Gonibeedu, we lived like an ordinary poor family. In 8th grade, I joined National High School at the B.R. Project. The place was a hub for sports and cultural activities, and I became one of the student leaders in my school.

One more thing I need to mention. In Gonibeedu village, two Kodava community families and one Kodagu Gowda family have settled. P. M. Ravi Anna, a member of the Gowda family, had a significant influence on my reading habits. At the time, in 1984, he subscribed to various Kannada weeklies, including Sudha, Prajamatha, Tushara, Karmaveera, Mayura, Taranga, Kasthuri, and Mangala, and I had the opportunity to read them, which improved my reading habits.

"Near the school, on the way, was the District Central Library in Kote, and I was naturally drawn to it."

There was an office clerk, G. Panduramgappa (G.P.), who handled the library period. He would quickly bring books to our tables, and we had to read in pin-drop silence for 45 minutes. Since I was a good student, he would also take me to the cupboards, and I would

help bring books to the class along with one or two other students. Those three years greatly influenced me.

Later, I joined the 11th and 12th standards at Sahyadri Science College in Shimoga. After that, I enrolled in a diploma course and later completed my B.A. at a degree college affiliated with Kuvempu University near my village. Eventually, I completed my Master of Library and Information Science from the same university.

Do you wish to mention any mentor or support who encouraged you at this stage of your journey?

SK: I would not be where I am today without my brother, Mr. Karthura K. Harish Kumar. When we lost our father, while I was in the 7th standard, he stepped up and took on the



With brother [in middle] and his friend at a coconut farm. **K.K. SURESH KUMAR**

financial responsibility so that I could continue my education. Because of his constant encouragement and guidance, I was able to move to Bangalore and join the Indian Institute of Management Bangalore (IIMB) Library as a Graduate Apprenticeship Trainee. That was where my career truly began. Watching his generosity taught me that life is far more meaningful when we look after one another.

One of my brother's close friends, Mr.

Mustak Ali Khan (Ramegowda), was also a wonderful mentor. I will always be grateful for the financial support and

encouragement he gave me when I was just starting out.

How did you decide to pursue Library and Information Science?

SK: Getting into Library Science was actually quite unexpected. After my degree, I initially applied for History, Economics, and Political Science. However, during a general discussion at our college, a couple of our lecturers mentioned a new Library Science course at Kuvempu University, which was just a kilometer away. They told us that the program had started only two years earlier, that it was an excellent subject, and encouraged us to apply. Since I had always been interested in reading, I decided to apply to the Library Science program as well.

So, I applied for all four courses at Kuvempu University in 1995. When the first list was announced, my name was not on it, which was quite disappointing. But about 15 days later, an offer letter from the Library Science department arrived at our house in the village. My mother and I were absolutely overjoyed. Without a second thought, I decided to accept it.

"Watching his generosity taught me that life is far more meaningful when we look after one another."

Eventually, the offer letters for History, Economics, and Political Science also arrived, but by then my mind was already made up. I joined the Library Science program, and once again, my brother provided the financial support I needed.

I was also an active NSS member at the university and was chosen for the North India NSS programme at Kuvempu University. I had the opportunity to visit Uttar Pradesh twice, in 1995 and 1996, and it was a wonderful experience.

If you had not pursued Library and Information Science, what other career do you think you would have chosen?

SK: I have always had a deep passion for the Kannada language, literature, and journalism. I am quite proud of my Kannada writing, and even today, I feel that, given the opportunity, I would have loved to pursue it professionally. I have been profoundly influenced by Navodaya Kannada poets and writers such as Kuvempu, D.V. Gundappa (D.V.G.), Bendre (Ambikatanayadatta), G.S. Shivarudrappa, Masti Venkatesh Iyengar, K.S. Narasimhaswamy, Shivarama Karantha, V.K. Gokak, Chandrashekhara Kambara, Poornachandra Tejaswi, Lankesh, and Ravi Belagere.



With renowned Kannada Journalist and writer Ravi Belagere. **K.K. SURESH KUMAR**

My love for writing naturally drew me to journalism as well. In fact, in 1999, I completed a diploma in journalism and ranked third. During that time, I also had the opportunity to interact with the late journalist Ravi Belagere. However, as it happens in life, my path eventually took a different direction.

Could you tell us about your doctoral research—your advisor, your thesis topic, and the questions you set out to investigate?

SK: In 2007, I enrolled in the PhD programme at Mangalore University under the supervision of Dr. M. K. Bhandi, University Librarian. Shri V. Savanur of the M. S. Ramaiah Library also encouraged me during this process. However, due to a personal issue, I was unable to continue my research. Later, in 2011, I enrolled in Kuvempu University's PhD programme.

Alright! My research topic was *Library Resources and Services in Secondary Schools of Bangalore Districts: A Comparative User Study*. I completed this work at Kuvempu University in the



Dr. K.C. Ramakrishnegowda, Kuvempu University
K.K. SURESH KUMAR

Shimoga district of Karnataka under the guidance of Dr. K.C. Ramakrishnegowda, the former University Librarian. My research aimed to investigate the status of library resources and services in school libraries across the rural and urban districts of Bangalore. At the same time, I wanted to explore how effectively teachers and students were utilizing these facilities.

For the study, I selected 60 schools from the Bangalore Rural district and 93 from the Urban district. To gather the necessary data, I designed two separate questionnaires—one for students and another for teachers. I collected data on the physical and operational status of

these libraries, including library space, operating hours, budgets, furniture, and the overall organization of their collections. Beyond the infrastructure, I also gathered information on user patterns. I wanted to understand why students and teachers visited the library, the challenges they faced, and their opinions about the services provided. I also evaluated their use of Information and Communication Technologies (ICTs).

Despite several drawbacks and bottlenecks, the study found that school libraries were useful for both teachers and students in improving their general knowledge, competence, and teaching skills. However, many teachers and students also reported that their reliance on school libraries for academic needs had not increased significantly.

What led you to choose this particular research topic, and what was the Ph.D. journey like for you?

SK: Many people wonder why, while working at a private university like Amrita University, I chose to focus on secondary school libraries. I am asked this question quite often. In my opinion, secondary education forms the foundation for higher education and for acquiring the skills needed for lifelong learning. Therefore, library culture, reading habits, and information literacy should be cultivated at an early stage of a student's life so that the habit of learning continues throughout life.

Since secondary schools provide basic education for all students, it is important to know whether they actually possess functioning libraries. Well-equipped, open-access school libraries not only encourage students to use resources but also help them learn through self-observation, self-study, and peer discussions. Having noticed the issues highlighted in newspapers and magazines, along with my own observations, I felt that research in this area would have the greatest impact. That is why I chose this topic.

“...library culture, reading habits, and information literacy should be cultivated at an early stage of a student's life so that the habit of learning continues throughout life.”

My thesis was a significant milestone in my academic career. I learned theories and concepts that I could not have understood without undertaking such extensive research, and I remain grateful to everyone who guided and supported me throughout the process.

My advisor constantly encouraged me, and his guidance greatly inspired my work. Whenever I faced challenges, his reassurance and practical feedback kept me moving forward from the beginning to the very end. I could not have completed the research or learned nearly as much without him. Working under him and learning from his expertise remains one of the greatest opportunities of my academic career.

You were accepted into the Graduate Apprenticeship Training program at the IIM Bangalore Library. What was that experience like, and what did you learn from your training?

SK: After my postgraduate studies, my teachers encouraged me to apply to the IIM Bangalore library apprentice program.



At IIM Bangalore during training program in 1997. **K.K. SURESH KUMAR**

It was a completely new world to me. I had seen the library at Kuvempu University, but the IIM Bangalore Library in 1997 operated 24 hours a day, which was quite a wonder to me. That is where I truly realized the immense importance of a library. I still vividly remember seeing students deeply engaged in reading throughout the day and even at night.

Once a month, for a few days, the male trainees had the opportunity to work the night shift from 10 PM to 6 AM alongside a permanent staff member. All three floors of the library remained active under minimal lighting. We worked in the ground-floor circulation section and, whenever required, assisted users in other sections as well. It was truly a wonderful and formative experience for me.

I will never forget Shri Chikkamalliah, Librarian at IIM Bangalore, for his support and guidance throughout my library career. He has been one of the best mentors in my life. He is now almost 80 years old, and I continue to visit him at his home and seek his blessings.

What was your employment experience like at Essae–TAPMI, and what lessons did you carry forward from your time there?

SK: That period of my career was quite memorable. After completing my library training at IIM Bangalore, I joined the Essae–T. A. Pai Management Institute (TAPMI) Academy in Bangalore, where I worked as a librarian for four years. The academy was a joint venture between the Essae Group and the TAPMI in Manipal, which provided the academic expertise.

Because the chairman of the Essae Group, S. A. Chandran, had his office at the academy, I had the opportunity to interact closely with him. He was an excellent management trainer and a yoga guru. It was from him that I learned the core principle of Kaizen², or continuous improvement, a mindset that has stayed with me ever since.

You seem to have learned a lot from him.

SK: Yes! I still remember what an avid reader he was. He frequently borrowed management

²[Kaizen (Japanese: 改善, "change for the better") is a philosophy that emphasizes continuous improvement through small, consistent steps. More at <https://en.wikipedia.org/wiki/Kaizen>]

books from our library. What truly amazed me was that such a prominent industrialist would not even use the lift just to get a book. Instead, he would walk up the stairs, personally visit the library, search for the books himself, sign the book card, and take the books. Seeing a person of his stature, amidst a busy schedule, demonstrate such genuine love for libraries and books, along with a simple, humble attitude, is something I will always remember. I also noticed that whenever he stood up, he always pushed his chair back into its place. On one occasion, he gently pointed out that I had forgotten to do the same. I will never forget that moment. From that day forward, I have always made it a rule to push my chair back in, and I have maintained that habit throughout my life. A habit that, I think, everyone should care about.

What was your employment after ESSAE-TAPMI?

SK: I joined Amrita and worked there for almost fifteen years. Initially, it was an engineering college affiliated with Visvesvaraya Technological University, Belagavi. I had the privilege of being the first librarian at the Amrita Bangalore campus. Three years later, the engineering colleges in Karnataka, Tamil Nadu, and Kerala, together with the science and medical colleges, became part of Amrita Vishwa Vidyapeetham, a private university. The institution is led by Mata Amritanandamayi Devi, affectionately known as Amma.

And what was it to build and develop the library there?

SK: At the Amrita Bangalore campus, I served as the founding librarian from 2002 to 2017. Starting from scratch, I was actively involved in every aspect of developing the library. With a team of fifteen library staff, we served over 2,600 undergraduate and postgraduate students, more than 160 faculty members, and over 350 non-teaching staff. The library housed more than 50,000 resources, engineering and MBA databases, and around 150 journal subscriptions.

“From that day forward, I have always made it a rule to push my chair back in, and I have maintained that habit throughout my life.”

We developed dedicated sections for circulation, periodicals, reference, digital resources, theses and project reports, publications, a reading hall, and photocopying services. We also implemented library management software and maintained library hours from 8 AM to 10 PM. Around 500 users regularly visited the library. I met Amma [Guru Mata Amritanandamayi] several times, both at the university and during ashram programs in Kerala and Bangalore, and received her blessings. My journey at Amrita



During inauguration of book exhibition at Amrita University. **K.K. SURESH KUMAR**

was very memorable, and I remain in touch with the management and many faculty members.

How did you come to join HRI, and what were your first initiatives at the library?

SK: My joining HRI in December 2017 was accidental. I never expected to move to North India, particularly to Prayagraj.

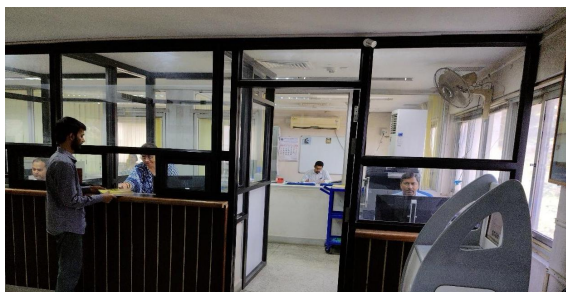
One of our first priorities was to modernize the library. We shifted many of our services from manual to electronic systems, increased the seating capacity, and gave the library a new look. We also adopted RFID technology-KIOSK along with the Koha open-source library management software, which greatly improved our services. Slowly, users began to recognize the library as an active and important department within the institute.

Since HRI is primarily devoted to frontier research in physics and mathematics, how does this influence the library's collection policy and the services it provides?

SK: Yes. Regarding the collection policy, our focus is 99% on mathematics and physics. Service-wise, there is not much difference. In librarianship, it does not matter what type of library we work in. Whether it is an academic, research, or public library, the specific work may vary, but the core services are largely the same. At HRI, we strive to provide high-quality services and a user-friendly experience.

To what extent are you involved in supporting the research activities on campus?

SK: I support the entire research lifecycle of our researchers. This includes providing Open Access and publishing support, as well as supporting author workshops and webinars. I also regularly share scientific information with the research community. In addition, we provide access to a wide range of e-resources, bibliographic databases, and specialized tools for citation management and research data management.



K.K. Suresh Kumar (near the whiteboard) with the staff of the HRI Library. **K.K. SURESH KUMAR**

How large is the HRI Library team, and how do you ensure that the staff remains up to date with evolving technologies and research needs?

SK: Currently, the library has nine staff members and remains open from 8 AM to 2 AM, past midnight. We regularly attend software training programmes, author workshops, and similar professional development events. Traveling to conferences,

seminars, workshops, and training programmes also helps us stay up to date with the latest technologies. In addition, the DAE Consortium and the One Nation One Subscription (ONOS) initiative under INFLIBNET conduct regular training programmes on their resources and services, all of which we attend.

What, in your opinion, is the true role of a library in an academic institution? What do you think people often misunderstand about using a library?

SK: Facilitating learning is one of the most important roles of a library. If users are not actively engaged with it, they miss much of its value. Simply visiting the library is not enough; making proper use of its resources is what brings people closer to success. The knowledge contained in libraries is like an ocean, and there is a tremendous amount to discover. We could write an entire book on this subject.

What role does the physical library play in today's digital age of information and online resources?

SK: Physical libraries are metamorphosing to include both physical and virtual resources. Instead of only collecting print materials, they now serve as collaborative workspaces, technology labs, and much more. Researchers may visit less frequently to issue and return books or browse the shelves, but they spend more time accessing e-resources and engaging in discussions with their peer groups within the library.

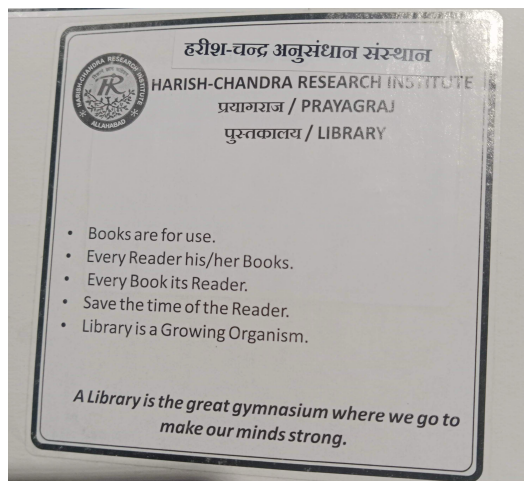
What does a typical day as the librarian at HRI look like, and what aspects of your work do you find most appealing?

SK: Each day is different and challenging. I am service-oriented, so I am happy to serve users in various ways. Some of my main responsibilities include sending official emails and letters, communicating with publishers, and gathering information from the internet. Handling routine library activities, communicating with colleagues, assigning work, and resolving issues are also part of my daily responsibilities. What distinguishes me is that I leave the library each evening with the same enthusiasm with which I arrived.

What are your hobbies and interests outside your professional life?

SK: Yes. During my childhood, I collected stamps and cricket photo clippings from newspapers. My other hobbies include reading, listening to lyrical songs, gardening, and watching adventure movies.

"The knowledge contained in libraries is like an ocean, and there is a tremendous amount to discover."



Bookplate used in HRI Library books, displaying S. R. Ranganathan's Five Laws of Library Science.

ANVESHANĀ

HRI also opens its library to students from nearby schools and colleges, which is your initiative. Could you tell us about this and



Library space at HRI. K.K. SURESH KUMAR

what inspired you to take such an initiative?

SK: As I said earlier, I am a service-oriented person who flourishes in libraries. I find it incredibly rewarding to meet the challenge of serving our users in diverse ways. Yes, HRI encourages students from nearby villages to use the library for their academic development. We provide library access to students from the 10th standard up to the master's level. HRI is an institute dedicated to serving society.

What challenges arise when a research library opens its resources to external users, and why is this practice still not common at many institutions?

SK: In general, most research and academic libraries do not provide free access to their collections for external users. Balancing the needs of internal and external users is a major responsibility, and library staff often face many challenges in serving both groups.

Many libraries have adopted different models, and most charge external users for access. Decisions regarding library access depend on each library's policies and the norms of its institution. While providing access offers many benefits, it also presents significant challenges for the library and the institution.

Have you observed differences in the way high school students and HRI's graduate students, PhD scholars, and postdoctoral researchers seek knowledge?

SK: Yes, there are significant differences in information-seeking methods, and they are closely connected to academic maturity and study goals. School students generally depend on readily available and highly structured materials for their studies. In contrast, PhD scholars and postdoctoral researchers rely on independent and critical inquiry to build new knowledge, moving beyond acquiring existing information toward conducting original research and developing deep, specialized expertise.

Beyond its regular services, does the HRI Library take any special initiatives for students and the wider community?

SK: Yes. These initiatives include organizing library visits for high school and college students, delivering library lectures there. All of these programs are supported by our library facilities, which offer comfortable spaces, rich resources, and strong institutional support. Local students benefit greatly from these outreach efforts.

"HRI encourages students from nearby villages to use the library for their academic development."

Does the HRI Library collaborate with other libraries? If so, how do these collaborations benefit the library and its users?

SK: Yes, we maintain inter-library loan services in various ways. Within the DAE (Department of Atomic Energy) library network, we share journal articles and electronic resources without restrictions, except for physical copies of books. Additionally, HRI is a member of DELNET in New Delhi, which provides inter-library borrowing services to more than 9,900 institutions across India. Through this network, we can request printed books from other libraries as well as electronic copies of journal articles.

The HRI Library holds a wide range of materials in mathematics and physics and is regarded as one of the finest collections in the country. With 25,000+ textbooks reference books, 38,292 bound volumes, 2,452 e-books, 13,434+ ONOS journals, databases, life-time archives, print journals, magazines, newspapers, theses, etc., the library is a rich source of collection.

Apart from this, the HRI Library maintains close contacts with approximately 20–30 libraries across India to obtain journal articles. We also occasionally communicate directly with authors, publishers, and vendors to obtain articles that may not be available through other channels.

Let us talk about open-access initiatives. How does the HRI Library support and promote open access?

SK: Our library has implemented open-access initiatives by self-archiving theses and actively assists users by sharing information on open-access publishing. We

also regularly provide updates to our users on open access and other relevant academic developments.

HRI is part of the One Nation One Subscription (ONOS) initiative. How has this benefited the institute's researchers and library users?

SK: This is an initiative of the Central Government. In earlier days, researchers often struggled to obtain even a single photocopied journal article for their studies. Today, more than 13,400+ journals are available to users, marking an extraordinary development for Indian research. Our members can easily access these resources through the institute's IP-based access.

Do you think there is sufficient awareness of open-access initiatives? If not, what more needs to be done?

SK: No. Greater awareness is needed among users. However, I feel that many readers are still not fully receptive to an open-access environment. Several changes are needed in government and UGC policies, the quality of open-access journals, authors' attitudes, user awareness, and publication fees.

More authors are coming forward to publish their work in open-access journals. At the same time, governments and regulatory bodies should formulate clear policies or mandates to support and standardize this matter.

How did the COVID-19 lockdown affect the library and its management?

SK: The COVID-19 lockdown had a dramatic and transformative impact on libraries and their management, serving as a catalyst for a rapid, forced transition to digital services. While physical library spaces were closed to users, library administrations had to adopt alternative approaches, moving away from traditional in-person service models toward digital-first, contactless, and hybrid models.

Could you briefly explain what journal binding is and why it is done?

SK: Based on the size of the journal, several separately published issues are usually sent together for binding into a single volume. Various types of bindings are available, including leather binding, half calico, full calico, and ordinary binding. Among these, full leather binding is the most durable. However, with the growing popularity of e-journals, journal binding is gradually declining, as it is also a highly space-intensive practice.



Apprentice in bookbinding at the Göteborg Book Fair 2023 **BOBERGER**
THROUGH WIKIMEDIA COMMONS



Top-left: Suresh Kumar [far right] at Gonibeedu Village after his father's death. Bottom-left: With brother at his wedding. Right: With daughter and wife at a traditional wedding.

K.K. SURESH KUMAR

What advice would you give to those who are serving in the profession or aspiring to become librarians?

Knowledge is an ocean, and we are all lifelong learners. Only those with a spirit of service can truly provide quality services to everyone; otherwise, managing a library can easily become an overwhelming profession.

Anveshanā shares a similar origin story—we seek to respect knowledge and its many methods of inquiry, while remaining grateful for every hand that contributes to its pursuit.

Is there any message you would like to share with our readers? Who are the people you would especially like to acknowledge for their support throughout your journey?

SK: Reading the stories of scientists and information providers is truly fascinating. Such stories stimulate readers and illuminate the path of reality.

"Knowledge is an ocean, and we are all lifelong learners. "

Throughout my education, research journey, and professional development, I have deeply cherished the time I spent with my beloved father, the late Mr. Karthura A. Kushalappa, and my loving mother, the late Mrs. Karthura K. Susheela. They were a tremendous source of inspiration in my life, and I am profoundly grateful to God Almighty for the blessing of my parents.

Once again, I would like to express my gratitude to the late K. A. Achappa and the late Smt. Seethamma (Uncle and Aunty), the late P. M. Ravi Anna, Mr. Mustaq Ali Khan (Ramegowda), Prof. B. S. Biradar, Prof. Mallinath Kumar, the late Dr. K. C. Ramakrishne Gowda, Mr. Chikkamalliah, Dr. M. K. Bhandi, and Mr. V. Savanoor for their support throughout my journey.

I also express my deepest appreciation to my graceful wife, Mrs. Karthura P.B. Leelavathi (Shabna), whose spiritual, moral, and physical support has been invaluable throughout my journey, and to my lovely daughter, Karthura S. Bhamini Changappa, for her patience and inspiration in both my personal and professional life.

Finally, my humble pranam to the lotus feet of goddess SARASVATI,

sarasvati mahābhāge vidye kamalalocane |
vidyārūpe viśālākṣi vidyāṃ dehi namostute ||

[Sarasvati, the glorious one, who is the embodiment of knowledge, lotus-eyed, whose form is the whole universe, and the one with the broadest perspective – please grant me knowledge. My salutations be unto you.]

This interview was conducted over email correspondence.

HOW MATHEMATICIANS CHANGED THE WORLD OF FINANCE, FOREVER.

BY SRUTHI SUBRAMANIAN

Mathematics and Finance have traditionally been perceived as disjoint fields. At least in India, many students choose commerce because they do not enjoy mathematics, while those who do are often steered towards science by default. Commerce and finance are taught in a way that is largely disconnected from mathematics, at least at the school level. Formulas are used, but they are not proved, and the underlying mathematical ideas are rarely emphasized. At the same time, so-called pure mathematicians have often preferred to separate their work from practical, real-world applications and have not necessarily wanted to be associated with finance. It is therefore no surprise that when mathematicians first began walking into the world of finance, they were met with more suspicion than enthusiasm.

Many traditional investors dismissed the notion that mathematical models could rival time-tested fundamental analysis, which relied on company earnings, dividends, and financial statements to determine stock prices. Meanwhile, many academics viewed the shift of talent from pure mathematics to finance as a waste of intellectual talent. None of this deterred Jim Simons (1938 - 2024), an MIT graduate and UC Berkeley PhD, who had his eye on markets from a young age. From scratch, he built the Medallion Fund and Renaissance Technologies, producing extraordinary annual returns of 66% before fees, far surpassing even Warren Buffett. He achieved this by bringing mathematics to the heart of trading. This is the story of how Simons and a small group of mathematicians sparked the Quant Revolution.

Mathematics was always central to Jim Simons' identity. From an early age, he knew he wanted to pursue the subject. His PhD research focused on the geometry of multi-dimensional curved spaces, and later, while working with Shiing-Shen Chern, he co-developed the Chern-Simons invariants, concepts that would eventually find important applications in physics¹. After completing his doctorate, Simons taught at MIT and conducted research at Harvard before joining the Institute for Defense Analyses (IDA) as a codebreaker, continuing his own

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¹For instance, it later provided the grounds for the understanding of Topological Quantum Field Theory.

mathematical research alongside government work. The open and collaborative culture at the IDA left a lasting impression on him and later became a defining feature of Renaissance Technologies. After leaving the IDA, Simons helped build the mathematics department at Stony Brook University before eventually turning his attention fully toward finance, where he founded the Medallion Fund and Renaissance Technologies (RT).

Jim Simons always envisioned an automatic trading system, one capable of generating profits with minimal human intervention. Early on, however, the process still relied on a combination of computers and people. Medallion's first trading system, known as the 'Piggy Basket', was designed for currency markets and produced vectors indicating the proportions of various currencies to buy. Human traders then manually executed trades to match those recommendations. Over time, Simons, together with prominent figures like Henry Laufer, Peter Brown, and Robert Mercer, developed increasingly sophisticated mathematical strategies. Their work eventually led to the creation of fully automated systems driven entirely by mathematical models, bringing Simons' vision of a "money-making machine" to life.



Jim Simons at his New York office in 2007.

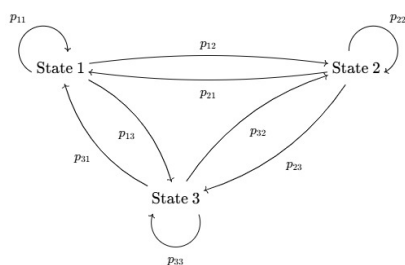
BILL CRAMER

Many of the mathematicians Simons encountered during his years at UC Berkeley, the IDA, and Stony Brook later became instrumental in building Medallion, with some even joining him as partners. James Ax, a mathematician famous for the Ax-Kochen theorem, whom Simons had persuaded to join Stony Brook, introduced trading strategies based on moving averages. Sandor Straus, a UC Berkeley PhD who worked at Stony Brook's Computer Center, focused on building clean and reliable datasets, an effort that later proved critical to the success of Henry Laufer's automated systems. Rene Carmona, then a professor at Princeton, joined the firm and experimented with kernel methods, early machine learning techniques, to identify patterns in financial data. Simons was initially cautious with these methods due to their lack of explainability. Another important figure was Elwyn Berlekamp, who had crossed paths with Simons at MIT, Berkeley, and the IDA. Berlekamp had worked with Claude Shannon (yes, Claude AI is named after this person!), the father of information theory, and himself made major contributions to combinatorial game theory. At Renaissance, he encouraged the firm to move toward short-term trading and argued that success in markets, much like success in casinos, required being correct only slightly more than half the time. Even a small statistical edge, applied consistently, could generate enormous profits.

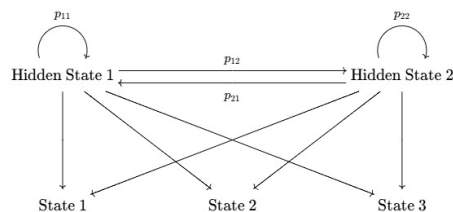
The lack of explainability in methods like kernel models was one of the major obstacles to integrating computers into finance. Many quantitative techniques, both then and now, operate as black boxes: the system recommends trades, but no one can fully explain why those recommendations work. This naturally made investors hesitant to trust such models. Ironically, this became both an obstacle and an advantage for Simons. In the early years, potential investors were reluctant to fund Renaissance Technologies because they could not clearly understand the logic behind its strategies. Yet, when the firm eventually built its trading systems, it deliberately combined signals that were intuitively understandable with others that had no obvious explanation. Competitors tended to avoid strategies they could not rationalize, which gave Renaissance an edge. By embracing patterns that others distrusted, the firm created systems that were both highly effective and difficult for rivals to predict or replicate.

The Quant Revolution unfolded alongside rapid advances in technology and the growing influence of computer science. Improvements in computing power and data processing enabled the analysis of the enormous datasets that Sandor Straus had painstakingly assembled. Several figures connected to quantitative finance were also deeply involved in the development of modern computing and machine learning. Jeff Bezos, before founding Amazon, worked at D. E. Shaw Co., one of Renaissance's rivals, which used statistical arbitrage models for trading. Leonard Baum, Simons' first partner, together with Lloyd Welch, developed the Baum-Welch algorithm, a method applied not only in finance but also in speech recognition. Similarly, the IBM research team from which many people eventually joined RT, starting with Peter Brown and Robert Mercer, worked on speech-to-text systems and machine translation, early forms of what is now known as natural language processing. Straus' insistence on clean, structured data and the use of historical information to predict future behavior also anticipated techniques that are now central across industries, from online recommendation systems and targeted advertising to intelligence analysis. Many of the mathematical models used during the Quant Revolution relied on identifying patterns and probabilities in seemingly unpredictable systems, much as in astrophysics, which Simons also had an affinity for. One important framework was the Hidden Markov Model, which is used in conjunction with the Baum-Welch algorithm. The model below (left) denotes a Markov Model, with the transition matrix P , whose element p_{ij} gives the probability of moving from the i^{th} state to the j^{th} state at any point in time. This matrix is fixed, consistent with the assumption that future outcomes depend only on the current state rather than the entire past. The $(t + 1)^{th}$ state depends only on the $(t)^{th}$ one.

Hidden Markov Models extend this idea by assuming that some underlying factors affecting the system remain unknown, forcing the model to make probabilistic inferences from partial information. As shown in the diagram above (right), we assume a Markov model is running in the background. We then condition on each hidden state to find the probability of transitioning to an observable state.



A Markov Model



A Hidden Markov Model

Fig: Markov Model vs Hidden Markov Model COURTESY SRUTHI SUBRAMANIAN

Bayesian inference was used extensively to update probabilities. In Bayesian inference, we begin with a prior distribution that represents our initial beliefs about the probabilities of different outcomes. As new data becomes available, we condition on this information and apply Bayes' theorem to obtain a posterior distribution, which then serves as the new prior for future updates. This sequential updating of beliefs allows the probabilities of different events to evolve over time, making the model more adaptive and reliable. By incorporating the most recent information, Bayesian methods embody the principle that additional data can improve our understanding and lead to better predictions.

Bayesian inference updates our beliefs about an unknown parameter θ based on observed data D . The relationship is given by Bayes' theorem:

$$p(\theta | D) = \frac{p(D | \theta) p(\theta)}{p(D)}$$

- $p(\theta | D)$: **Posterior probability** of θ given the observed data D .
- $p(D | \theta)$: **Likelihood**, the probability of observing D assuming θ .
- $p(\theta)$: **Prior probability** of θ before observing the data.

At Renaissance, Henry Laufer used the vast datasets assembled by Sandor Straus to search for recurring patterns in historical market data. His models identified patterns tied to specific times of day, days of the week, or recurring reactions to particular events. His strategies were tested against historical records to assess statistical significance before deployment. Often, the exact reason these patterns worked remained unclear, but if the historical evidence supported them strongly enough, then the strategies were implemented regardless. Another widely used approach was the *return-to-mean* (or *mean reversion*) strategy, especially in *pairs trading*, which involves two historically correlated securities. If the price relationship between the

two assets deviated significantly from its historical average, traders assumed that it would eventually revert to its long-run mean. They then bought the relatively undervalued asset (**Long buy**) and simultaneously sold the relatively overvalued asset (**Short sell**), creating a market-neutral position that minimized exposure to broader market movements. When the price relationship returned to its historical level, the **trades were reversed** — the long position was sold, and the short position was covered, allowing the trader to lock in a profit approximately equal to the magnitude of the temporary deviation. Such lower-risk strategies were central to Medallion's success and contributed to its exceptionally high Sharpe ratio (the ratio of expected return to risk), allowing it to achieve unusually high returns while taking comparatively lower risk.

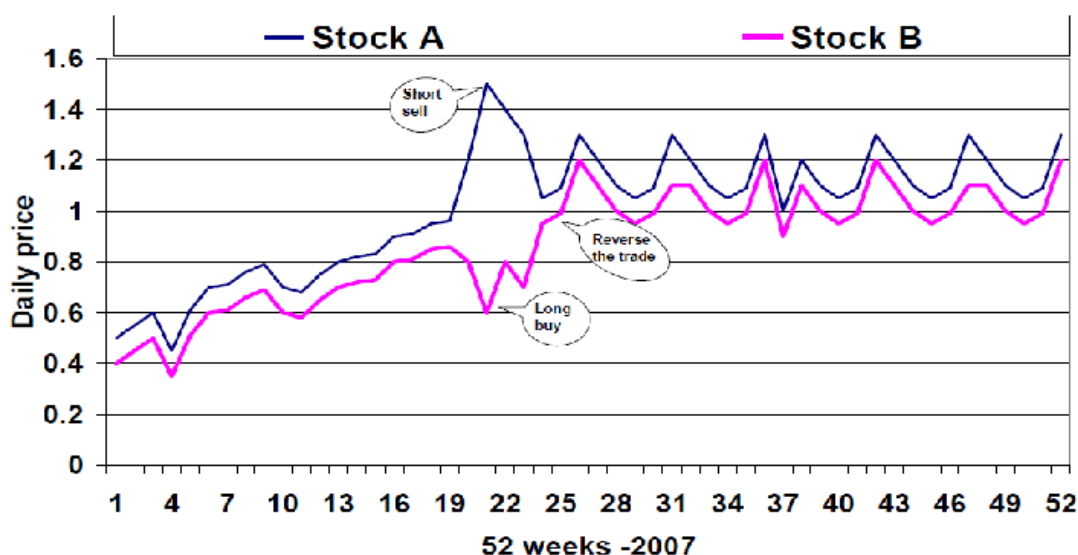


Fig: Pairs Trading Strategy REPRODUCED FROM [1] WITH PERMISSION.

Beginning in the 1950s, academic research witnessed a rapid growth in mathematical models designed to explain and predict financial market behaviour. Their significance is underscored by the fact that several of these contributions were later recognised with Nobel Prizes in Economics. Harry Markowitz's *Modern Portfolio Theory* introduced the concept of mean-variance optimization to determine the optimal allocation of wealth across multiple assets, balancing expected returns against risk. Building on these ideas, the *Capital Asset Pricing Model* (CAPM) of the 1960s used linear regression to relate an asset's returns to market returns, distinguishing between systematic and unsystematic risk and reinforcing the importance of diversification in reducing asset-specific risk. The 1970s then saw the emergence of the *Black-*

¹ Al-Naymat, Ghazi. "Mining pairs-trading patterns: A framework." *International Journal of Database Theory and Application* 6.6 (2013): 19-28.

Scholes model for option pricing, which drew upon stochastic calculus and modelled asset prices using geometric Brownian motion to derive the price of options (financial contracts that give the owner the right to buy/sell an asset at a fixed price, on a fixed future date). These developments laid the foundations of modern quantitative finance and continue to influence both academic research and industry practice.

MODERN PORTFOLIO THEORY

$$\mathbb{E}[R_p] = \sum_{i=1}^n w_i \cdot \mathbb{E}[R_i] = \mathbb{E}[\mathbf{w}^T \mathbf{R}_i]$$

- $\mathbb{E}[R_p]$: portfolio expected return
- w_i : weight of asset i
- $\mathbb{E}[R_i]$: expected return of asset i
- n : number of assets

$$\sigma_p^2 = \sum_{i=1}^n \sum_{j=1}^n w_i w_j \sigma_i \sigma_j \rho_{i,j} = \mathbf{w}^T \Sigma \mathbf{w}$$

- σ_p^2 : portfolio variance (risk)
- σ_i : volatility of asset i
- $\rho_{i,j}$: correlation between assets i and j
- Σ : covariance matrix of returns

$$\text{Sharpe Ratio} = \frac{\mathbb{E}[R_p] - R_f}{\sigma_p}$$

- R_f : risk-free rate
- The numerator is the excess return over the risk-free, and the denominator is the portfolio volatility

We can find the optimal portfolio by minimizing variance, or by maximizing the Sharpe Ratio, or by optimizing any measure relating risk and return in this setup.

OPTIMIZATION PROBLEM (MAXIMIZING SHARPE RATIO)

$$\max_{\mathbf{w}} \frac{\mathbb{E}[R_p] - R_f}{\sigma_p} = \max_{\mathbf{w}} \frac{\mathbf{w}^T \boldsymbol{\mu} - R_f}{\sqrt{\mathbf{w}^T \Sigma \mathbf{w}}}$$

- $\mathbf{w}$: vector of portfolio weights
- $\boldsymbol{\mu}$: vector of expected returns

CAPITAL ASSET PRICING MODEL

$$\mathbb{E}[R_i] = R_f + \beta_i \cdot (\mathbb{E}[R_m] - R_f)$$

- $\mathbb{E}[R_i]$: expected return on asset i
- R_f : risk-free rate
- β_i : beta of asset i
- $\mathbb{E}[R_m]$: expected market return

$$\beta_i = \frac{\text{Cov}(R_i, R_m)}{\text{Var}(R_m)} = \frac{\sigma_{i,m}}{\sigma_m^2}$$

- $\text{Cov}(R_i, R_m)$: asset and market returns covariance
- $\text{Var}(R_m)$: market variance

BLACK-SCHOLES OPTION PRICING

A *call option* is a financial contract that gives the holder the right (but not the obligation) to buy the underlying asset, usually a stock, at a fixed price, called the strike, on a fixed date, the expiry date of the options contract. A *put option* gives the holder the right to sell the underlying asset at the strike price on the expiry date.

$$C = S_0 \cdot N(d_1) - K \cdot e^{-rT} \cdot N(d_2) \quad P = K \cdot e^{-rT} \cdot N(-d_2) - S_0 \cdot N(-d_1)$$

C : call option price; P : put option price; S_0 : current stock price; K : strike price; r : risk-free rate (continuous); T : time to expiration (years); σ : volatility; $N(\cdot)$: standard normal CDF, where

$$d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}, \quad d_2 = d_1 - \sigma\sqrt{T}$$

The partial derivatives of these options are taken to find out how the prices change with respect to different factors, like time or the current stock price. These derivatives are popularly known as the Greeks.

The rise of quantitative finance also coincided with the emergence of Behavioral Economics, which emphasized the importance of human psychology in shaping market behavior. Emotions, biases, and collective reactions all influence how prices move, and many argued that quantitative models were, in essence, sophisticated tools for modeling human behavior itself. By analyzing how people had reacted to past events, these systems attempted to predict how markets would respond to similar situations in the future. As long as human behavior re-

mained relatively consistent, past data could serve as a useful guide. However, as quantitative trading becomes increasingly dominant and human-driven trading is declining, some question whether markets themselves are changing. This shift to more automated trading could make markets more stable and reduce volatility, but it also raises doubts about whether the future will continue to resemble the past. Interestingly enough, though, even the strongest advocates of quantitative methods recognized the limits of automation. When models underperformed, Simons himself occasionally intervened and adjusted the systems. Ultimately, the financial world operates through a balance between human judgment and automated systems, and maintaining that equilibrium remains crucial.

The Quant Revolution is far from over. While the first generation of quants showed that mathematics and statistics could uncover hidden patterns in markets, the current generation is exploring whether artificial intelligence can take things a step further by learning those patterns on its own. Hedge funds today increasingly rely on machine learning, natural language processing, and use data ranging from weather parameters to social media sentiment, blurring the boundaries between mathematics, finance, computer science, and data science. As algorithms continue to reshape financial markets, the same question remains as relevant as ever: Can mathematics ever fully capture the complexity of financial systems? The search for this answer continues to define the frontier of quantitative finance.

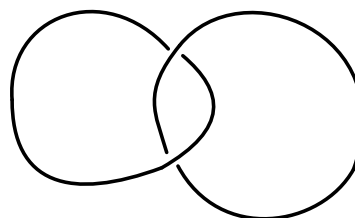
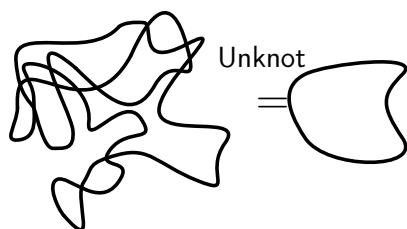
UNTIE THE KNOT!

BY PROGNAIPTO MAJUMDER

“In these days the angel of topology and the devil of abstract algebra fight for the soul of every individual discipline of mathematics.” - Hermann Weyl

INTRODUCTION

We instinctively know what a *knot* is. This article will be a tale of how knots are viewed through the lens of topology, and how a generation of mathematicians has worked to study them from a purely algebraic standpoint. For our purposes, we can agree upon a knot to be a string, possibly twisted or knotted, with no loose ends. A *link* is defined to be some number of knots arranged in some specific way in 3D space.



Hopf Link

In Greek mythology, an oracle claimed that whoever was able to untie an intricate knot tied by King Gordius would become the next ruler of Asia. Alexander the Great, unable to untie the knot, became impatient and swiftly cut it with his sword.

Initially, the best we can do is twist and turn with the knots without breaking or collapsing any of the strings. This ultimately is a topological question in mathematics. In the words of Edward Witten,

“In Einstein’s general relativity the structure of space can change but not its topology. Topology is the property of something that doesn’t change when you bend it or stretch it as long as you don’t break anything.”

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Later, we would find ways to cut up knots and re-glue them to study knots in an algebraic fashion. Mathematicians are simple folks, with a very generic philosophy towards life: give a man a fish, he will eat for a day; give a mathematician a fish, and he will try to define axiomatically what a fish is; next, he will aim to classify all fish and prove theorems regarding when to call two fish of the same kind.

The first serious study of knots arose when Lord Kelvin hypothesized that different molecules are different kinds of knots formed by stringlike vortices (of what?) in aether. In a rush to classify all molecules, Peter Guthrie-Tait jumped to describe all knots up to a given complexity, so that the first serious mathematical discussion on knot theory was done by a chemist.

CLASSIFICATION OF KNOTS

At this point, we run into one of the basic underlying philosophies of mathematics: how do we represent a knot mathematically, how do we study them, and when do we call two knots the same?

Knots are objects in 3D space, so when we look at them from one side and project them on a flat piece of paper, we need to take note of which string lies above and which one lies below. For simplicity, we assume that no three segments of the string ‘intersect’ at the same point when viewed as a projection onto some plane. Given such a diagram, we can construct the full knot in 3D space, so we have not lost any information. The difficulty begins when we look at a knot from two different ways- they might look like two different projections. We call two projections to be ‘the same’ if we can transform one into the other by some smoothly varying moves that keep the crossings invariant. One of the first important steps was taken by Kurt Reidemeister (and independently by James Waddell Alexander and Garland Baird Briggs), who proved that any two projection diagrams represent the same knot if and only if they can be related by a sequence of three very special moves called Reidemeister moves:

R₁: Twist and untwist in either direction.

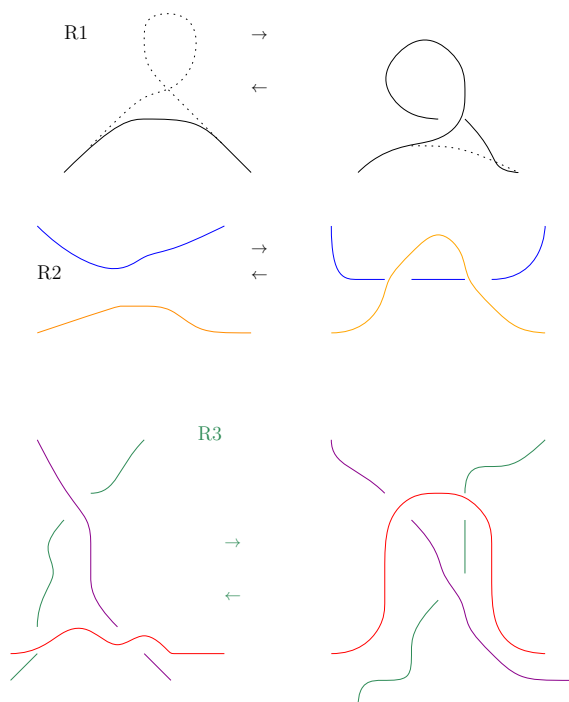


Fig: Peter Guthrie Tait’s tabulation of knots and their properties (has lots of redundancies!).

PETER GUTHRIE TAIT

R2: Move one loop completely over another.

R3: Move a string completely over or under a crossing.



Now, proving two things are the same is simple in theory; we just need to algorithmically find out a sequence of steps between two such knot diagrams. Brute force computation becomes useless due to the sheer size of computations, in which regard it might be interesting to note a result by Coward and Lackenby¹.

Theorem 1 *Let D and D' be link diagrams and suppose that D' is obtained from D by the addition or removal of an unknot summand. Suppose that D and D' both have at most n crossings. Then there is a sequence of at most $2^{10^{11}n}$ Reidemeister moves relating D and D' .*

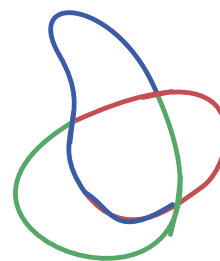
So, we ask a simpler question, how to show when two knots are NOT equivalent? To

get a concrete grasp of things, we shift our focus to two questions:

- Given a trefoil knot, is it possible to untie it to get a ring?
- Given a Hopf link, is it possible to separate the two rings without tearing them apart?

These two questions would give us an idea of *knot invariants*, which will be the main theme of our story hereafter, and which we will conclude with a mention of Vaughan Jones and Mikhail Khovanov.

To solve the second question, Gauss thought of the idea of what the induced magnetic field would be in the second loop when a current flows through the first. This is 0 for two non-linked rings and nonzero for the Hopf link.



Tricoloured Trefoil

For the first question, we define a tricolouring of a knot to be a coloring with three colors such that each strand receives one color, at least

¹Coward, Alexander, and Marc Lackenby. "An upper bound on Reidemeister moves." American Journal of Mathematics 136.4 (2014)

two colors are used in total, and at each crossing, the strands are either all the same color or all different colors. Using this we can show tricolourability is a knot invariant; and whereas the trefoil knot is tricolorable, the unknot (which we call the ring with no crossings or twists) is NOT.

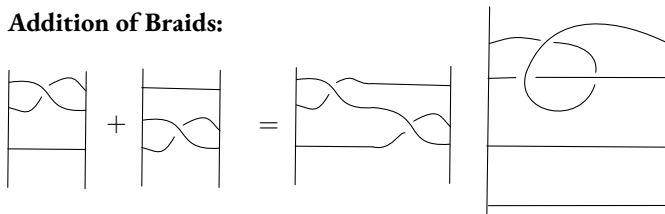
Classical knot theory gave rise to a plethora of knot invariants, each to address a very specific question or related to some very restricted class of knots. Over the course of years, a large number of simple intuitive questions regarding classification of knots began to be posed, without any strong technique generic enough to address all or most of these questions in one solid framework.

JONES POLYNOMIAL

Probably the first gigantic breakthrough came through the work of Vaughan Jones, for which he was later awarded the Fields medal (1990) which he accepted wearing the New Zealand rugby jersey. A functional analyst from New Zealand, Jones came across some nice representations of Artin braid groups while studying type II_1 algebra towers in his foundational paper 'Index for subfactors'².

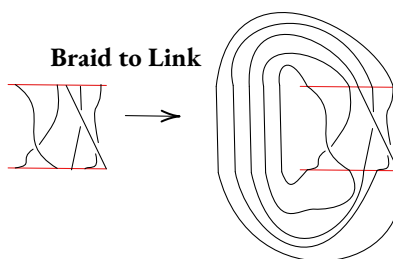
We will look at braids, which we can think of as strings with fixed endpoints at the top and bottom of the figure, each segment goes from some top peg to some bottom peg, and might be twisted in any way. The braids with a fixed number of pegs admit a kind of non-commutative 'addition', namely concatenation, and the group of all braids on $n+1$ is a well-known object in group theory, the braid group B_n . James Alexander showed that every link can be obtained by closing the ends of some braid. The works of Markov showed that two links are equivalent if and only if their underlying braids are related by a sequence of braid moves, well-known in group theory. Jones found that using the trace function of the representation, there was a polynomial associated with every braid.

Addition of Braids:



This is not a braid.
All strings should go from
left to right.

Braid to Link



² Available at <https://link.springer.com/article/10.1007/BF01389127>.

Kauffman interpreted the construction of the polynomial as a state sum. We can 'resolve' a crossing in one of the two ways so that we don't have intersecting curves. For every crossing, we have two choices, and we get (2^n) states. Jones' polynomial immediately answered many longstanding questions in knot theory, one of them being the question of amphichirality, i.e., when a knot is equivalent to its mirror image. Yet several questions remained unanswered. One such question was, is it true that the Jones polynomial being 0 implies the knot is topologically same as unknot? While this has a negative answer for links, it is still unknown for knots. Questions like this, and the lack of finer structure in the theory led to the quest of something called categorification in the context of knots, leading to the seminal work by Mikhail Khovanov.

KHOVANOV HOMOLOGY

Exposition to Homology: We look at a 1-dimensional chain complex, where we label the groups at each position by a 'degree'. The group at the i -th degree is named C_i . So we have constructed a much richer structure with maps that helps us to study knots and links far more efficiently. Furthermore, while this complex is not invariant, the successive quotients of image/kernel at each chain degree are indeed invariant, and is known as the Khovanov Homology of the knot or link. To get an idea of what is homology, we note as an aside, the homology (H^*) of the chain complex associated to a sphere (S^2):

Complex:	$\mathbb{Z}$	$\longrightarrow$	0	$\longrightarrow$	$\mathbb{Z}$
Degrees	2		1		0

Define the kernel to be all elements that map to 0. Then at degree 2, kernel is $\mathbb{Z}$. Then, we define homology at a degree to be the kernel of the outgoing arrow quotiented by the image of the incoming arrow. So, here $H^* \simeq \mathbb{Z}$ if $* = 0, 2$ and 0 otherwise. Khovanov homology involves a two-dimensional version of the above setup, where we have two different degrees, the chain degree and quantum degree, and the complex looks like a grid.

Categorification is a concept that we won't attempt to define in this exposition, but we can say that it adds more structure to objects and, more importantly, to the maps between objects. For instance, the natural numbers are categorified by n -dimensional vector spaces over a fixed field k , and the increasing relation of numbers translates to a map between vector spaces as the inclusion in the initial coordinates.

Khovanov did something similar with the state-sum model of the knot with n crossings. First, we label the crossings and get 2^n binary strings. Now, for each circle, we assign the vector space V , and each state gets assigned a tensor product of V 's. This comes with an inbuilt product and coproduct of V , and we obtain maps between the states that correspond to two circles merging (product in V) or splitting (coproduct in V). This constitutes something called a chain complex, which simply means that any two maps composed turn out to be 0. To add the final touch, we can show that the graded Euler characteristic, an algebraic property of the chain complex, is the Jones polynomial.

So we have constructed a much richer structure, using maps, that helps us study knots and links far more efficiently. Furthermore, while this complex is not invariant, the successive quotients of image/kernel at each chain degree are indeed invariant, and is known as the *Khovanov Homology*³ of the knot or link.

The study of Khovanov homology has given rise to a lot of beautiful phenomena and results, but to state the very least, we have:

Theorem 2 (Kronheimer-Mrowka) *If a knot has trivial Khovanov homology, it is the unknot.*

Dror Bar-Natan explicitly showed that this technique yielded stronger classification power by constructing links with the same Jones polynomial but different Khovanov homologies. The concept of Khovanov homology has opened a deep and rich connection between the topology of knots and the algebraic structures of braid groups. For example, Y. Teng in 2025 used a version of Khovanov homology to find the first known example of an exotic Lagrangian plane in $\mathbb{R}^4$, i.e., a structure in $\mathbb{R}^4$ that is topologically indistinguishable from a 2-d plane but can be distinguished by smooth maps.

OPEN QUESTIONS

There are a couple of questions we can look at (for math enthusiasts):

1. Each of the homology groups (calculated as $\mathbb{Z}$ homology), constitutes of a free part which is a direct sum of copies of $\mathbb{Z}$; and a torsion part, which is some finite abelian group. Now, while the dimension of the free part directly relates to the coefficient of some power of t in the Jones Polynomial, the meaning and consequences of the torsion term is an active area of research. It is a bit of a mysterious object without a well-understood geometric meaning yet. There are a number of conjectures around this, such as:
 - (*Shumakovitch*) The Khovanov homology of every link except the unknot, the Hopf link, their disjoint unions, and their connected sums, has torsion of order 2.
2. Another very useful technique to study knot theory is through knot Floer homology, which was developed independently by Ozsváth-Szabó (Heegaard Floer theory) and Rasmussen around 2002, and which was shown by Ozsváth-Szabó in 2005 to be connected to Khovanov homology via a spectral sequence, a result that finally led to the proof of Kronheimer-Mrowka of how Khovanov homology detects the unknot.

³By convention, it should technically be called Khovanov *cohomology*, since chains and their homologies have decreasing chain degrees. When degrees increase along the chain, we call it a cochain and the associated quotients to be cohomology groups.

RESOURCES PALETTE

SUGGESTED READINGS BY READERS

- **On the Calculation of Volume** by **Solvej Balle**

This book series by Solvej Balle delves into the notion of a time loop, but far more than that, into what time means when it is no longer something two people inhabit together. A woman finds herself stranded amidst the otherwise well-knit fabric we call time, while her partner continues to move through it, unaware. They begin to live different lives within the same house, sometimes sharing a day, sometimes merely sharing a space. It is less concerned with answering what happens than with asking what remains of a person when time itself refuses to move as expected.

- **Flowers for Algernon** by **Daniel Keyes**

Through Charlie's journey, Daniel Keyes explores intelligence, dignity, loneliness, and the deeply human desire to be understood with remarkable honesty and compassion. Every page invites the reader to question what it means to be intelligent, to belong, and to be loved beyond one's abilities. It is a profoundly humane novel that lingers quietly, asking for empathy.

- **The Importance of Being Earnest** by **Oscar Wilde**

Oscar Wilde writes an incredibly engaging and addictive play with this book. Every conversation is layered with humor, irony, and effortless brilliance that keeps the story constantly alive. Beneath all its laughter, lies a story about the roles we choose to play, the people we choose to impress. Wilde reminds us how easily appearances become a part of who we are, and how often sincerity is sacrificed for acceptance.

- **A Free Man** by **Aman Sethi**

This is a brilliant work of narrative reportage covering the lives of daily wage workers in Delhi. The book follows Aman's interaction and friendship with Ashraf, one of the many dehadi majdoors in Baratooti Chowk in Delhi, and his friends. Despite the unsettling and difficult nature of the labourers' lives, Aman shows remarkable reportage as well as writing that is funny, sensitive, and abstains from pontification and passing judgements. It is an extremely well-written text of journalism and speaks to the readers very naturally.

WEB RESOURCES

- **Detexify**—a project to help one find the LaTeX command for any symbol
<https://detexify.kirelabs.org/>
- Simons Center for Geometry and Physics Video Portal on Mathematics and Physics
https://scgp.stonybrook.edu/video_portal/

- **Millennium Mathematics Project (MMP)**—a maths education and outreach initiative for ages 3 to 19 and the general public
<https://maths.org/>
- **π -Base: Topology**—a community database of topological counterexamples
<https://topology.pi-base.org/>
- **Teach For India**—a nationwide movement focused at eliminating educational inequity
<https://www.teachforindia.org/>
- **International Youth Math Challenge**—an educational mathematics competition open to students worldwide
<https://iymc.info/en/>
- **Vāgdhenu**—a vṛtta (meter) aware śloka-to-chant text-to-speech system for Sanskrit
<https://prathosh.in/vagdhenu/>

UPCOMING CONFERENCES AND PROGRAMS

- Upcoming conferences in algebraic geometry maintained by Ravi Vakil
<https://virtualmath1.stanford.edu/vakil/conferences.html>
- Upcoming programs at Simons Center for Geometry and Physics
<https://scgp.stonybrook.edu/science/programs>
- Upcoming events at International Centre for Theoretical Physics
<https://www.ictp.it/home/scientific-calendar>
- Upcoming programs at ICTS
<https://www.icts.res.in/programs/upcoming>
- Current and Upcoming Thematic and Focus Programs at The Fields Institute for Research in Mathematical Sciences
<http://www.fields.utoronto.ca/activities/thematic>
- **International Congress of Mathematicians (ICM) 2026**
(Jul 23, 2026 - Jul 30, 2026) at Pennsylvania Convention Center Philadelphia, Pennsylvania.
<https://www.icm2026.org/>
- **Serre 100**
(Sep 15, 2026 - Sep 16, 2026) at Institut Henri Poincaré.
<https://serre100.sciencesconf.org/?lang=en>

- **Indian Mathematical Congress 2026**
(Dec 18 2026 - Dec 22 2026) at LMSI, Mumbai.
<https://lmsi.org/programmes/indian-mathematical-congress/>
- **Thematic Programme on Condensed Mathematics and p-adic Geometry**
(Jan 2027 - Jun 2027) at LMSI, Mumbai.
<https://lmsi.org/programmes/thematic-programme-on-condensed-mathematics/>
- **French-Japanese Conference on Arithmetic Geometry in Honor of Takeshi Saito and Takeshi Tsuji**
(May 31, 2027 - Jun 04, 2027) at IHES - Marilyn and James Simons Conference Center.
<https://indico.math.cnrs.fr/event/15993/>

Quaerendo Invenietis

ISSUED TO

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[za xa ni]: The beauty

The beauty of mathematics only shows itself to more patient followers.