Exploring the Quark Gluon Plasma with Bikash Sinha

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Abstract

This paper presents a personal account of the scientific and professional adventures of Bikash Sinha on the occasion of the celebration of his 60'th birthday held in Calcutta on Feb 7, 2005.

1 Introduction

It is a great honor for me to begin this meeting celebrating the accomplishments of Bikash Sinha.

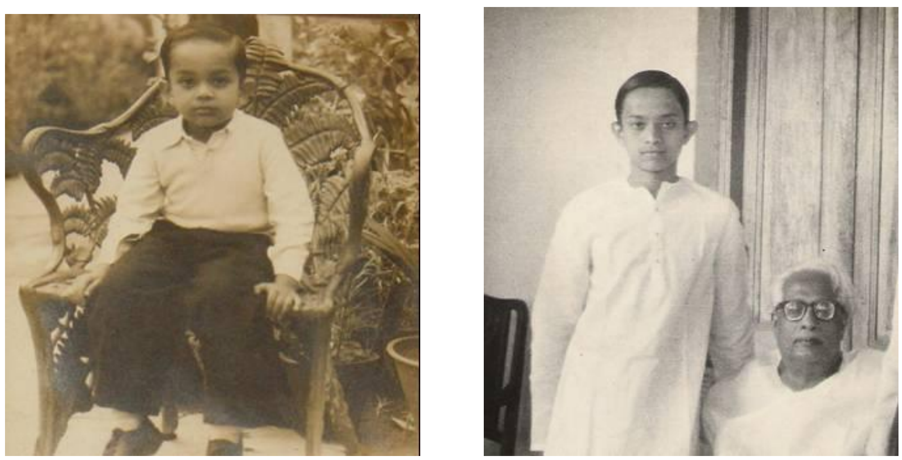
I have heard rumors that Bikash may be a little nervous about what we are about to say. Perhaps he is feeling like a 60 year old virgin on her wedding night. She has a vague idea of what will come, but not specific knowledge.

I guess part of this nervousness arises from the great pleasure that all of his friends have had in putting together these presentations. It must make Bikash nervous when people are laughing and standing around their computer screens, and when you come into the room the laughing stops and the screens go blank. But don't worry Bikash, there is nothing you can do.

I must say, that all conspiracies require inside information. I thank Yogendra Viyogi and Jan-e Alam for helping to provide this, and particularly Bikash's wife, Aparna, for providing beautiful family photos. Also my very good friend Dinesh Srivastava is responsible for all of the many insights he has provided me into the works of Bikash, and more generally to the impact Bikash has had on science in India.

This talk is about the growth of a young determined boy into a research scientist and one of the great movers of Indian nuclear science. You can see this transition in the photos below:

In the photo 1a, you see a child whose posture and facial expression shows his determination, a child for whom much is expected, and a child who will deliver those expectations.



a b

Figure 1: (a) Bikash as a very young boy (b) Bikash as a teenager with the famous physicist S. N. Bose.

In the photo 1 b, Bikash is an adolescent posing next to one of the great men of Indian science, S. N. Bose. Is it any accident that Bikash became interested in the properties of a matter at finite temperature, given the great discovery of Bose about statistics of bosons and the applications of this discovery for finite temperature systems?

The next photo 2a of Bikash and a cricket racket I like very much, as it shows Bikash simply enjoying what life and youth have given him.

The last photo 2b represents public recognition for his service and accomplishments in science and administration. He is receiving the Padma Shri award from the president of India. For those non-Indians who do not understand this award, it is a really big deal. It is given for extraordinary accomplishment in the fields of the arts, sciences and human endeavor. (A few days ago, I read letters to the editor in one of the local newspapers where people were protesting giving the award to a movie star because the award was reserved for serious accomplishment.)

a

b

Figure 2: (a) Bikash as young man enjoying life (b) Bikash receiving the Padma Shri award.

The point of this talk is to describe Bikash's journey in science, his accomplishments, what he has built, and what he is building.

2 Education at University of Calcutta

Bikash received his early science education at the University of Calcutta. The physics department there is shown in the picture 3. He received a Bachelor of Science with Honors in Physics in 1964.

The University of Calcutta was the first modern university in India, founded in 1857. Among the faculty associated with the University of Cal-

Figure 3: a Th physics department at the University of Calcutta.

cutta were three Nobel prize winners: Rabindrath Tagore, the poet philosopher and nationalist; Sir. C. V. Raman, famous for his discovery of Raman scattering; and Amartya Sen the mathematical economist famous for his work on welfare economics. In addition, both M. Saha, famous for his work on stellar dynamics, and S. N. Bose, the discoverer of Bose statistics were faculty members. Sir C. V. Raman and M. Saha are shown in 4a-b.

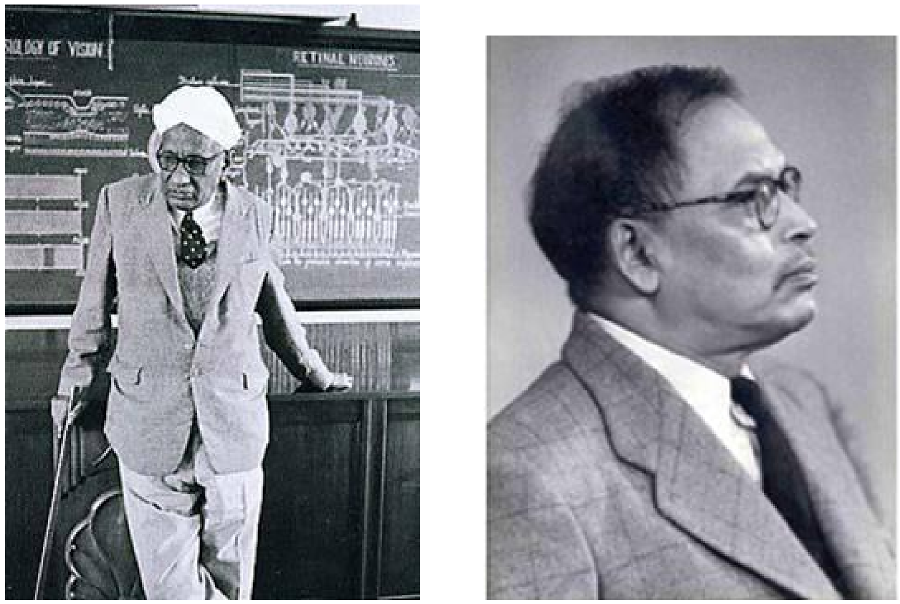
The university of Calcutta began the first medical school in Asia. It had the first science department in India. It had the first women's colleague in India. It provided the initial impetus for both the Saha and Bose Institutes.

3 Cambridge University and the University of London

Bikash went off to Cambridge University where he received his BA in 1967 and an MA in 1968 in Natural Sciences (with a physics Tripos). I think this is where he refined his famous and distinguished English accent. He went to London University and received a PhD in 1970. He became a Senior Research Fellow from 1970-1976 at King's College at the University of London.

Bikash's research was on the optical potential.[1]-[3] In particular, he recognized the importance of 2 body interactions including saturation effects which limits the nucleons from getting too close to one another. This idea of saturation has important consequences in another area now: the limiting of the growth of gluons of fixed size in a high energy hadronic wavefunction.

During 1970-1976, Bikash worked hard and was very productive, publish-



a b

Figure 4: (a) Sir C. V. Raman (b) Prof. M. Saha

ing 9 Physics Letters articles, 4 Nuclear Physics Articles, and 10 in"other journals" such as Physical Review Letters, Physical Review C, and Physics Reports. (I am a senior editor for Nuclear Physics A, so I am personally predisposed articles of high quality written for Elsevier journals.)

Perhaps most notable during his time in London, he began his long collaboration with Dinesh Srivastava.[4] In 1973 they wrote their first paper together: The Energy Dependence of the Optical Potential.

The cartoon below summarizes my impression about Bikash and Dinesh. The characters in the cartoon were both heros of the western movies of my youth: The Lone Ranger and Tonto, shown in Fig. 5. Analogous heroes must occur in Bollywood classics. The Lone Ranger is the central character, distinguished by the fact that in all situations, he is the hero. He is the origin of the phrase "Who was that masked man?" (I have never understood why he needed the mask.) His faithful companion is Tonto, an Indian brave (in politically correct modern English, a Native American warrior). Tonto would almost always work behind the scenes to insure that the Lone Ranger ended up the hero of each episode. Many people suspected Tonto of having great intelligence.

Figure 5: The Lone Ranger and Tonto trying to escape an ambush by angry Indians.

Of course, there are always times of stress, as illustrated, where the Lone Ranger and Tonto are surrounded by Hostile Indians (perhaps from somewhere out west.) In this case, Tonto seems to want to make a run for it. As President Nixon's head of the Justice Department said to staff members of the president who were under indictment for misbehavior during the Watergate scandal: "When the going gets tough, the tough get going." I do not think that the double meaning was intended.

4 Back to Bombay

In 1976, Dr. R. Rammana invited Bikash to join the Nuclear Physics Division of the Bhabha Atomic Research Center. It was here that his interest developed on the Quark Gluon Plasma.

He began his program at BARC studying hot spots in nuclear collisions and density dependent delta function interactions. A photo of BARC is shown in Fig. 6.

In 1983 he wrote his first paper on the QGP.[5] The title and abstract of the paper are:

Figure 6: The Homi Bhabha Atomic Research Center

Universal Signals of the QGP

Abstract:

It is shown that the ratio of production rates of photon to muon pairs and pions to muon pairs from a QGP are independent of the space-time evolution of the plasma fireball and thus are universal signals of the quark-gluon plasma

The idea behind this work is that pions reflect the entropy produced in the collisions, and this is conserved in late stages of the collision. Energetic photons and dileptons are made early in the collisions and do not rescatter, so they reflect the initial conditions.

This is a great paper. It is seminal. It remains modern even more than 20 years after its publication. It has provided the basis of much of the later work by the Calcutta group.[6]-[13]

5 "Oh, Calcutta"

In 1984, Bikash moved to Calcutta to become head of Research Facilities and Computer at the Variable Energy Cyclotron Center in Calcutta. As anyone knows, establishing a group and taking a leadership role involves taking responsibility for young people. This is illustrated in Fig. 7. There is a famous American movie starring the present governor of California, Arnold Schwartzenegger, called Kindergarten Cop. It is the story of an undercover

Figure 7: Bikash SchwartzenSinha.

policeman who has to do secret work as a teacher in a kindergarten. I have taken the liberty of putting Bikash's head on Arnold's body. Wouldn't this make for a much better governor of California? Would it make a better Bikash? Among the young people attached to Swartzenegger are Jan-e Alam, Dinesh Srivastava and Shibaji Raha (artfully disguised). Others of you can identify yourselves as you please.

At Calcutta, Bikash began to make his mark: He established a research group on Quark Gluon Plasma. He arranged the first Indian school on the Quark Gluon Plasma in India in 1986. He took a leadership role in developing the talents of "young brilliant scientists". (The quotes are present because these are Bikash's own words.). He initiated participation in the WA 80-95 experiments at CERN in the search for direct photons, a search which is now a component of every QGP experiment.[14] In 1988 he organized the first of the International Conference on the Physics and Astrophysics of the Quark Gluon Plasma at the Tata Institute in Bombay.

In 1987, he began his long collaboration with Shibaji Raha.[6] This collaboration is illustrated in the cartoon in Fig. 8. These guys did very good

Figure 8: Shibaji and Bikash having a physics conversation.

physics, but I think like all good scientists, they had to work a little to communicate their ideas to one another. They had no problem communicating their ideas to others.

6 The ICPAQGP Series

The International Conference on the Physics and Astrophysics began with a very exciting meeting at the Tata Institute in Mumbai in 1988. Excellent people came to this meeting. Leon van Hove's regal presence and inimitable style were memorable. Angela Olinto and Charles Alcock were much excited about strange quark matter, and the possible formation of strange stars. This had an impact on Bikash and Shibaji's work, and has led to the experiment which will soon be underway in Darjeeling. From this beginning, Charles tried to interpret these strange stars as the origin of dark matter, and he began a now famous experiment to use gravitational lensing to search for such objects.

Ed Shuryak, Mitya Diakonov and Genya Zinoviev all arrived from Russia. They had many adventures, including when they went to the Taj Mahal after the meeting, they took a cab from Delhi, and said they had just come from Bombay. The taxi driver asked them what they did. They answered they were physicists. Then the driver said,"Oh, you must have been at the ICPAQGP." I learned from this story to never underestimate the influence of Bikash.

Before the meeting, there was a school in Jaipur at the Alsisas Havelli. My wife and I were there together and fell in love with the old style of architecture at this classic building. There were peacocks flying around in the garden, and monkeys in the trees. We got to know and appreciate Bikash as a result of this school. We got to taste the delicate concoctions of the famous Polo Bar at the Rambaugh Palace. (During this trip, my wife Alice, rode her first camel, and developed a love affair with this disgusting beast which has lasted for the past almost 20 years. I can tell you many stories about Alice and camels.)

The picture, Fig. 9 below was on the poster of this meeting, and I guess has been the icon for this meeting ever since. When I first saw the photo of the statue, I did not look carefully. Dinesh, at the meeting in Bombay, told me to look at it carefully, then smiled in a Dinesh sort of way and said "See, they are creating the universe". I had this poster on display in my office in Fermilab for several months after the meeting. These offices were made of glass so passers-by could see the poster. It was eventually stolen, I suspect by someone who found it to be too "spicy". Too bad, I really loved that poster.

Of course there were a number of such meetings afterwards: Calcutta in 1993, Jaipur in 1997 and 2001 and the meeting beginning tomorrow in Calcutta. All of the meetings have had excellent science, and the organization was always spectacular. Every meeting has a set of stories attached to it, and an exposure to a different aspect of Indian culture and science.

One story is in Jaipur in 1997, I was with my very good friend Jean-Paul Blaizot, who did not know Bikash well at the time. He was curious about Bikash because he knew I had such a high level of respect for what he was doing. One night at the first Jaipur meeting, we went to an organizational meeting for the next conference in the series, and Bikash was sitting surrounded by a circle of his Indian colleagues. He was quietly listening, and at

Figure 9: Creating the Universe in Calcutta.

the end of the meeting went back over his understanding of how to proceed, and then did a check off of everyone's assignments. He was firm and assertive in the Bikash style, which all of his colleagues understand. It was quite clear that Bikash was bringing order from chaos. Jean-Paul understood.

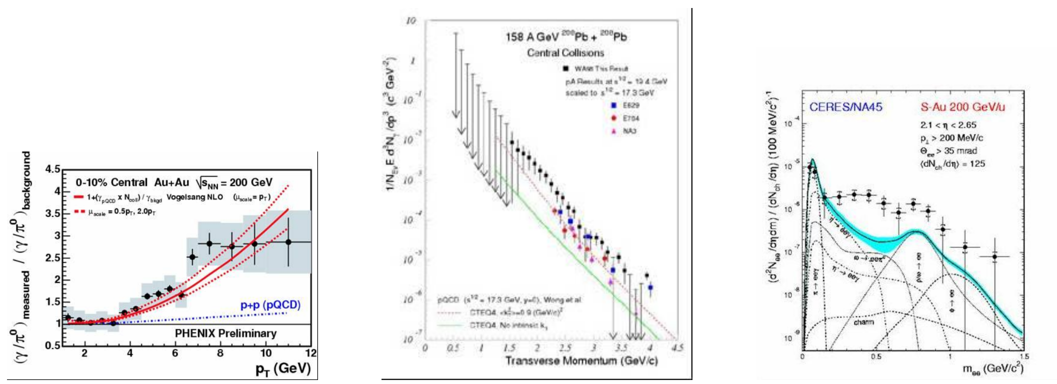
7 QGP and Electromagnetic Probes

Let me begin by quoting the famous translation of Ovid's The Metamorphoses by Garth and Dreyden:

"Before the sea, and this terrestrial ball,
And Heaven's high canopy that covers all,
One was the face of Nature, if a face,
Rather a crude and indigested mass,
A lifeless lump, un-fashioned and un-framed,
Of jarring seeds, and justly Chaos named,
No sun was lighted up, the world to view,
No moon did yet her blunted horns renew,
Nor yet was earth suspended in the sky,

Nor poised, did on her foundations lie,
Nor sea about the shores their arms had thrown,
But earth and air and water were on,
This air was devoid of light and earth unstable,
And waters dark abyss un-navigable"

In the figure below, you see some of the experimental results which were stimulated by Bikash's work on the Quark Gluon Plasma, Fig 10. In the



(a) (b) (c)

Figure 10: a Hard photons measured at RHIC b Soft photons measured at CERN c Soft dileptons measured at CERN .

plot of the WA80-95 data, there is a depletion of photons relative to what had been expected from hadron gas models. This was predicted by Bikash and Dinesh.[5]-[10] In CERES, there is an excess of dileptons which has been attributed to the QGP. In the results from PHENIX, one has just measured the hard photons and they are in agreement with computations from perturbative QCD.

The work of Bikash and colleagues in India has not been restricted to theory. Calcutta has built essential elements of the photon detectors for WA80-95, STAR and ALICE. Without their efforts, results such as these shown in the figures would not exist.

In the Fig. 11 below, I show the STAR Photon Multiplicity Detector 11. The first results from the PMD will be shown in the meeting over the next week.

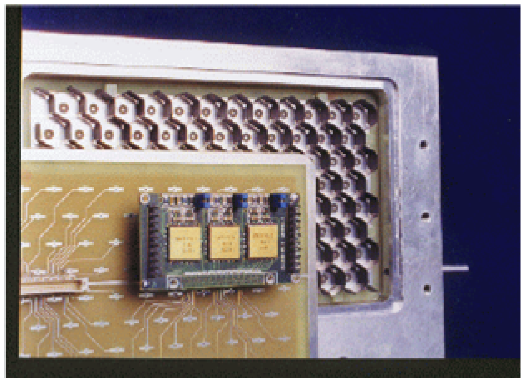


Figure 11: The Photon Multiplicity Detector in STAR .

8 Bikash Sinha: Cosmology and the QGP

One of the most beautiful and poetic conceptions of cosmology comes from the Chandogya Upanishad. This was written 3000 years ago. To me it presents in metaphor the deepest problems of modern cosmology:

In the beginning, the world was just being. Some people would no doubt say, this world was just non-being, and from non-being was produced. But how could that be so? How could being be produced from non-being? On the contrary, the world was being alone. One being without a second.

Being thought to itself: "May I be many, may I procreate". It produced fire. Fire thought to itself "May I be many, may I procreate". Fire produced water. Therefore when a person perspires, it is from fire that water is produced. Water thought to itself: "May I be many, may I procreate". Water produced food. And when it rains, there is abundant food, for it is from water from which eating is produced.

Being thought to itself: "Having entered into these three divinities by means of this living self, let me develop names and forms"

A Dialog Between a Student and a Teacher.

Bring me a fig from that tree

Figure 12: The goddess Lakshmi in a reproduction of an old painting.

It is here.

Break it.
It is broken.

What do you see now?
Very fine seeds.

Now break a seed.
It is broken.

What do you see?
Nothing at all.

In truth, that subtle essence which you do not perceive is from what this giant fig tree arises. Believe me, that which is subtle essence, this whole world has that essence for itself.

Fig. 12 shows a beautiful painting of Lakshmi. She, among other things, is the goddess of light.

9 Bikash Sinha: The Astrophysics Connection

In every ICPAQGP, there has a been a major amount of time devoted to the discussion of the astrophysics of the Quark Gluon Plasma. (See the Fig. 13) One of the reasons for this is that in the early universe, the Quark Gluon

Figure 13: We begin discussing the big bang.

Plasma was the matter at times less than about 10^{-5} *sec*, as shown in Fig. 14.

At the time of the first ICPAQGP, there was considerable speculation that a first order phase transition to the QGP might generate large scale density fluctuations. This is illustrated in Fig. 15. For temperatures $T > T_c$, the phase transition temperature, the system is homogeneous. A little below T_C, nucleation centers for, the system reheats to T_c, and a mixed phase of QGP and hadronic phase is made. Initially, the regions of hadronic gas are very small, but as the system expands, more and more of the volume becomes hadronic gas and less QGP. The size scale of these droplets can grow to be quite large, of the order of the size of the universe at $t \sim 10^{-5}$ *sec*

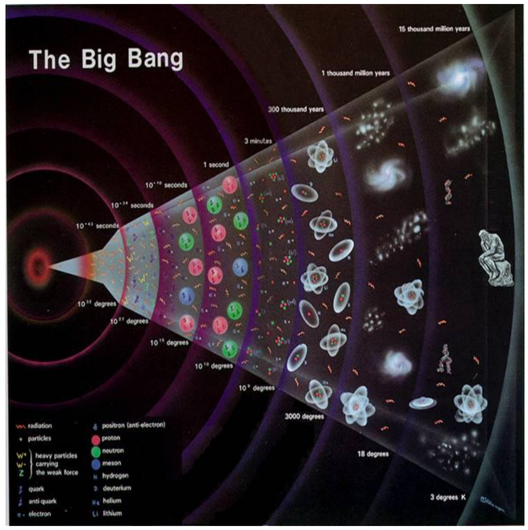


Figure 14: A pictorial history of the big bang.

This can result in density fluctuations which survive long after the transition. To understand this, recall that in the deconfined phase, the mass of a quark is of order T_c, so the probability to have a baryon number fluctuation is $e^{-M_q/T} \sim 1$. On the other hand, in the hadron gas, the baryon has of order N_c quarks, and the mass is of order $M_P \sim N_c T$ so that the probability for a baryon number fluctuations is of order e^{-N_c}, which is very small. Most of the baryon number gets trapped in the region of the QGP. After the QGP has evaporated, the baryons must diffuse to uniformity, but diffusion can take a very long time.

Early estimates of this time suggested that one might have baryon number inhomogeneities which could last until nucleosynthesis, and the various element abundances might be affected. I think that we now believe that the QGP phase transitions is either not a first order phase transition, or is so weak, that this does not occur.

Bikash was interested in this scenario from a different point of view.[16]-[19] He wanted to use the big bang to make strangelets. If strange quark matter is the stable ground state of nuclear matter, one can make droplets out of such matter. The decay time for ordinary matter into the droplets is long enough so that in the absence of some seed of very high energy density QGP, matter is stable. Such strangelets have roughly equal numbers of up

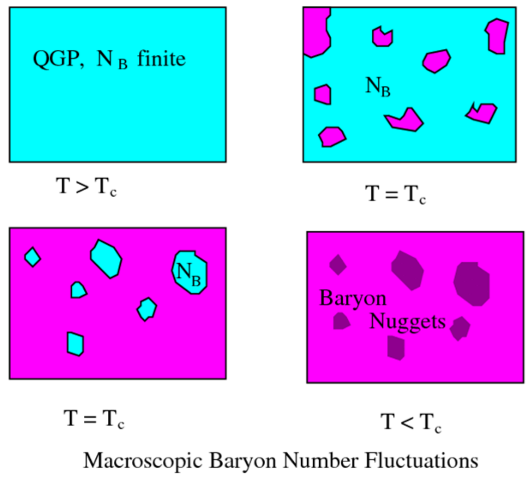


Figure 15: A hypothetical QGP phase transition in the early universe.

down and strange quark, whose charge adds up to zero, as shown in Fig. 16. This means that as a function of baryon number, the Coulomb self energy

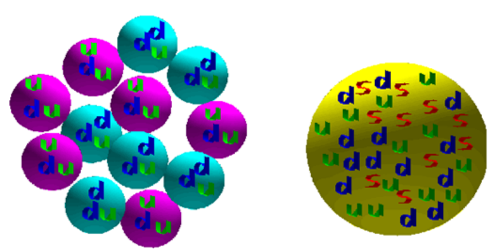


Figure 16: Nuclear matter and strange quark matter.

is never very large. The Coulomb self energy is what makes large nuclei unstable. Here, when the size of a droplet is large enough that the Coulomb self energy is substantial, the droplet is larger than the Bohr orbit of an electron, and the system becomes neutralized by the electrons. One can therefore make droplets of strangelets, which are at nuclear matter density, of any large size one can imagine. For example, one can make a house or a planet out of strange quark matter.

It was hypothesized that in the big bang one might make such strange quark droplets as shown in Fig. 17. This is probably not so likely in light

Figure 17: The primeval QGP making strangelets.

of what we now know about the QGP phase transition. Nevertheless, they might be made in neutron star collisions, or the formation of black holes, or even possibly very rarely in heavy ion collisions, as illustrated below 18.

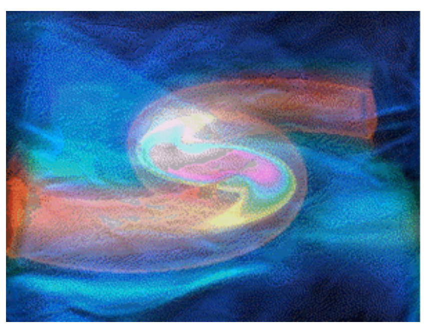


Figure 18: The a pictorial representation of the evolution of the collision of neutron stars.

There have been experiments to search for small strangelets, in heavy ion collisions with negative results. There may be some evidence from Centauro events in cosmic ray collisions. (Note the strange picture of the Centaur 19. For anyone who is concerned about the political correctness of the illustration, remember: It is only a naked horse.)

Figure 19: An artists conception of a centaur.

Bikash was involved in trying to see if one could make and detect strangelets, as shown in Fig. 20. He was excited by the work that his friend Charles Alcock did to look for strange stars using gravitational lensing. Together with Sibaji Raha, he pushed for an Indian cosmic ray experiment to look for strangelets. This experiment is near Darjeeling, and will begin operation soon.[20]

10 Bikash Sinha: Nurturing the Young

Why do good people like Bikash get involved in the world of physics politics and administration? Surely not because they enjoy it! Two reasons drive Bikash. The first is that if one wants to understand nature, one must build structure and organize people to carry out research. The second is, that if a scientific field is to flourish, it must have bright young people entering the field.

These young people must be protected from the maelstrom and chaos of funding fluctuations, and positions must be made for them, Fig. 21a.

This necessarily involves competition from other with different agendas. One must make sure that when they are in their most productive scientific career, that they are not overloaded with bureaucratic chores, Fig. 21b.

One must also expose young people to culture. The young people in science come from many back grounds. Physicists share a common love of music, art, and literature. Bikash has always encouraged this appreciation and understanding, Fig. 22a.

Figure 20: Bikash thinking about strange quark matter.

At the first ICAQGP, I remember a wonderful get together in Mumbai where one of Bikash's friends entertained us with sitar music. Finally, one must broaden the physics horizons of the young. This is sometime done by bringing young colleagues into contact with the distinguished senior members of our community, Fig. 22b.

The major nuclear physics collaborators of Bikash, many of whom WERE young people (some still are) are:

V. R. W. Edwards, D. Srivastava, F. Duggan, R. J. Griffiths, S. Moszowski, S. Raha, A. K. Chaudhuri, D. N. Basu, B. Datta, S. Chakrabarty, J. Alam, P. Sarkar, S. Chattopadhyay, M. Mustafa, B. Dutta Roy, B. Patra, S. Banerjee, S. K. Ghosh, B. Mohanty, and A. Rahaman.

and of course

the members of WA80-05, STAR, and ALICE.

Bikash has been an author of over 150 peer reviewed scientific publications.

a

b

Figure 21: a Bikash protecting the young. b Bikash cutting red tape.

11 Bikash Sinha: The Larger World of Science

Bikash has written 33 articles of general interest which have been published in the media. Some of the titles I found most interesting were:

- “The Changing Scenario of Nuclear Physics”, Science Today (1979)
- “Nuclear Power in India”, Weekly DESH (1983)
- “The Craziness Necessary for Research Exists in Calcutta More Than Anywhere Else”
- “Why Are We Wasting Our Talent”. The Telegraph (1991)
- “The Soviets Do Not Mind Shedding Tears in Public”, The Telegraph (1991)
- “Sales Talk and Vodka Among the Test Tubes”, The Telegraph (1993)
- “Electrified by a Nuclear Vision”, The Telegraph (1993)
- “Onuclearo is not a Nightmare”, Business Economic” (2000)

I love some of the titles of these articles. There is nice irony of ”Why Are We Wasting Our Talent?” There is gentle teasing of Bikash’s colleague when he

a

b

Figure 22: a Bikash enjoying the cultural side of life. b Bikash greeting the Nobel prize winner Abdus Salam to India.

talks about the crazy people from Calcutta. I really like "Onuclearo", but in spite of my best efforts was not able to figure out what it was. I guess it really is a nightmare.

Bikash also was central in establishing the Radiation Medicine Center in Kolkata as part of VECC.

He also has done some recent work about abnormal helium abundance in thermal hot springs in Bakreswar and Tantloi, and their correlation with geological activity. I come originally from the Pacific Northwest where there is a lot of geological activity, so I read these articles with much interest. (Perhaps the bottom line is that if your colleagues start talking with high squeaky voices, run like hell?)[21]

12 Bikash Sinha: Major Honors

Bikash has won so many honors for his work, that if he wore all the medals he would probably embarrass a Russian General. These include

- S. N. Bose Centenary Award 1994
- Fellow of Indian Academy of Sciences, Bangalore
- Fellow of Indian National Academy of Sciences, New Delhi

- Fellow of Indian Academy for Sciences, Allahabad
- DAE Raja Ramanna Prize 2001
- Pandya Endowment Memorial Lecture Award 2001
- Rais Ahmed Memorial Lecture Award 2001
- Fellow of 3'd World Academy of Sciences 2002
- Padma Shri Award

I include in the photos Fig 23, pictures of Bikash at celebrations of the Padma Shri award. The photo in Fig. 2b, shows him actually receiving the award. This is a really big deal!

a b

Figure 23: (a) Bikash is a bit nervous?. (b) Party time!.

13 Bikash Sinha: Major Accomplishments

One of the major accomplishments of Bikash's career is nearing completion now here in Calcutta. It is the building of the superconducting cyclotron. I show picture of the magnet coil, and the wrapping of wires around the magnet 24.

a b

Figure 24: (a) The superconducting magnet. (b) Wrapping wire around the magnet.

Since it is superconducting, one needs a really big refrigerator, also shown in Fig. 25. There is also a photo of visiting dignitaries associated with the cyclotron: Shri Satyabrata Mookherjee: Honorable Minister of State, Statistics and Program Implementation, Planning, Atomic Energy, Space, Commerce and Industry; Dr. Anil Kakodkar, Chairman AEC and Secretary, Dept. of Energy.

a b

Figure 25: a The refrigerator for the magnet. b VIPs

I understand that the cool down has started, and perhaps the magnet will have been energized.

14 Bikash Sinha: Major Responsibilities

We all know Bikash Sinha is a very busy man. He is

- Director: Saha Institute
- Director: VECC
- Vice chancellor, West Bengal University of Technology
- Scientific Advisory Committee to Cabinet, Govt. of India, 1997-present

I am really surprised by the amount of responsibility Bikash has taken, and the substantial and important accomplishments he has achieved.

In the tradition of the renaissance, a man is the sum of his accomplishment, Fig. 26. A great man, leaves more than the sum of his accomplishments. There is an intangible essence which exists in the minds and spirits of his colleagues who love and respect him.

Figure 26: Da Vinci: The symbol of European Renaissance.

15 Acknowledgments

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