

Homi Bhabha – an appreciation and a hope*

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Homi Jehangir Bhabha's birth centenary in 2009 was a significant occasion for Indian science in general, and for physics in particular. Many celebrations were held spanning a two-year period (2008–2010).

Naturally there have been a profusion of articles, accounts about Homi Bhabha and his achievements, and what he created for us, by many who worked closely with him. These include pieces by M. G. K. Menon, B. V. Sreekantan, D. Lal, B. M. Udgaonkar, Obaid Siddiqui and G. Venkataraman. Many appeared in the January 2009 and April 2009 issues of *Physics News*¹ of the Indian Physics Association, including recollections by several mathematicians. In *Current Science*, Spenta Wadia² has written on 'Homi Jehangir Bhabha and the Tata Institute of Fundamental Research' (TIFR) in the 10 March 2009 issue; there was also a piece by B. A. Dasannacharya³ in the 10 June 2009 issue. There is a beautiful article by V. Singh⁴ in the May 2009 issue of *Resonance* on 'Bhabha's contributions to elementary particle physics and cosmic rays research' (taken with permission from *Physics News*). And TIFR has produced a beautiful diary for 2009 devoted to Bhabha.

Going back a little bit in time G. Venkataraman's book⁵ *Bhabha and his Magnificent Obsessions* appeared in 1994; and the July 1998 issue of *Resonance*⁶ dedicated to Bhabha has many fine articles, including by Sreekantan and Venkataraman.

In the light of all this, it is difficult to see what I can say that is different or new. I was very distant from him, I had seen him at the weekly TIFR colloquium in the Old Yacht Club several times during 1959–1960; the closest encounter was once on the staircase, when I was going up and he was coming down. There is little new that I can say, certainly my aim is not to present a complete survey of all he did. What I will

*Based on an Invited Lecture in the Inaugural Session of the 'Homi Bhabha Birth Centenary Symposium on Hyperbolic Partial Differential Equations and Related Topics', held at the TIFR Centre for Applicable Mathematics, Bangalore, during 20–24 July 2009. Reprinted from *Physics News*, January 2011.

then try to give you is an appreciation from a very great distance, a personal view which will at times turn personal, in the spirit of the saying, 'a cat may look at a king'.

Family background

To begin, I should tell you about his family background, and his very close links to Bangalore. These are important and maybe of particular interest to all.

His paternal grandfather, Hormusji Bhabha, was Inspector General of Education in the Old Mysore State, a highly respected person. His father, Jehangir Hormusji Bhabha, grew up in Bangalore. He then studied Law in Oxford, came back and joined the Mysore Judicial Service. Then after marriage he moved to Bombay. Homi Bhabha's mother Meherbai was granddaughter of Dinshaw Petit, a leading figure of the Bombay Parsi community and a great philanthropist (Figure 1). His father's sister, also Meherbai, was married to Dorab Tata, son of the great J. N. Tata, who founded the Tata empire and conceived of the Indian Institute of Science (IISc), Bangalore, in 1896. J. N. Tata died in 1904; then his son Dorab pursued his father's vision, and IISc came into being on 27 May 1909. Later that year, Homi Bhabha was born on 30 October in Bombay. So for

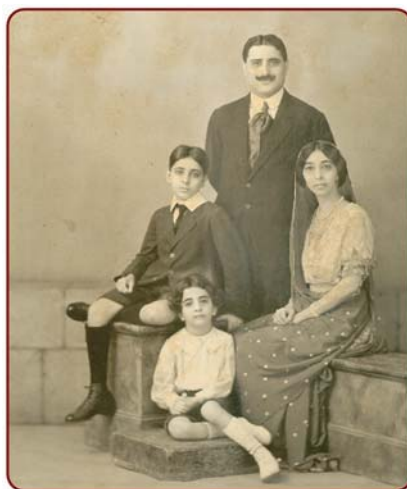


Figure 1. With parents and brother Jamshed (courtesy: TIFR Archives).

him, IISc was his uncle's institute. And in 2009, two centenaries were celebrated.

S. Chandrasekhar was exactly one year younger, being born on the very convenient date 19-10-1910. His centenary was celebrated in 2010. I will say something later about their contacts.

From now on, 'Bhabha' will mean 'Homi Jehangir Bhabha'. You can see that he came from a really aristocratic background, with very high family connections to the house of the Tatas. In later life he was extremely close to J. R. D. Tata, Pandit Jawaharlal Nehru and Rustom Choksi among others. I might quote this sentence from George Greenstein right away⁷: 'There is not the slightest doubt in my mind that Bhabha would never have achieved what he achieved had it not been for his aristocratic background and personal connections.'

Early education, years in the West

Bhabha's school and college education, brilliant throughout, were in Bombay: the Cathedral and John Connon School, then Elphinstone College, and then the Royal Institute of Science. In 1927, he was sent to Gonville and Caius College in Cambridge to study mechanical engineering (Figure 2). Both his father and his uncle Dorab wanted him to join the



Figure 2. In Cambridge (courtesy: TIFR Archives).

Tata Iron and Steel Company. But upon reaching Cambridge, or soon after, he had a change of heart and an intense desire to change to theoretical physics. He wrote to his father in 1928: 'Physics is my line. I know I shall do great things here. ...I am burning with a desire to do physics. I will and must do it sometime. It is my only ambition. ...I therefore earnestly implore you to let me do physics.'

This permission was given conditional on completing the Mechanical Tripos examination. Bhabha did so in first class in 1930, and then switched to physics. You may recall that similarly Dirac came to physics via electrical engineering and Eugene Wigner through chemical engineering. Bhabha passed the Mathematical Tripos also in first class, and for two years learnt physics from Dirac and Neville Mott. The scene in physics at that time was that quantum mechanics had been created during 1925–1927; quantum electrodynamics had been inaugurated by Dirac in 1927, with contributions later also by Heisenberg and Pauli; relativistic quantum mechanics had been initiated by Dirac in 1928 with his discovery of the wave equation for the electron. By the 1930s, the questions in the air were: What is the nature of the nuclear force? Does quantum mechanics work in the nucleus? Because of Waller's and Oppenheimer's discovery of ultraviolet divergences, does quantum electrodynamics break down in high energy phenomena? Bhabha was drawn, swept into all these developments. He was obviously greatly influenced by Dirac, as was Harish Chandra some years later. In 1935, he completed the Ph D under the guidance of R. H. Fowler, son-in-law of Ernest Rutherford. Incidentally, Dirac himself and Chandrasekhar too were Fowler's Ph D students.

Bhabha's major contributions during the twelve-year period – 1927 to 1939 – spent in the West have been beautifully recounted in Singh's article. He did a lot of work on positron phenomena, and clarified the role of exchange effects in electron–positron scattering. Completed in 1935, this is called Bhabha scattering. The comparison process of electron–electron scattering – the two are closely related by what is called the substitution law – was studied by Christian Moller and is called Moller scattering. This is a beautiful and practically useful piece of work by Bhabha, done years before the more modern, streamlined, elegant, mani-

festly relativistic and gauge-invariant calculational methods were developed by Feynman and Schwinger in the 1940s.

In 1937, Bhabha and Heitler (and independently Oppenheimer and Carlson) presented their cascade theory of cosmic ray showers – establishing that quantum electrodynamics did not break down in these phenomena, but was consistent and agreed with observations. Over the succeeding years this theory, QED, went through amazing developments, especially in the late 1940s – until in 1985, Richard Feynman could say⁸: 'The theory of quantum electrodynamics has now lasted for more than fifty years... At the present time I can proudly say that there is *no significant difference* between experiment and theory!' It has been tested to an accuracy of one part in 10^{10} or so, and is sometimes called the jewel of physics.

Also in 1937, Bhabha carried out a penetrating analysis of the 'penetrating' component of cosmic radiation, and was led to a brilliant prediction – there had to be a new particle about 100 times the mass of the electron. (The reference is 'On the penetrating component of cosmic radiation', *Proc. Roy. Soc. London*, 1938, **164A**, 257–294.) They were found in 1938 and are called μ mesons.

Bhabha was in the forefront of physics at that time, close to both theoretical and experimental advances. He was very much a part of the scene and in a group photograph taken at Copenhagen in 1936, you see him alongside Pauli, Heisenberg, Bohr, Born, Peierls, Weisskopf and others. As far as I know, he was not involved in nuclear physics, as Heisenberg and Wigner were, or in astrophysics to any significant extent. Dirac too does not seem to have worked significantly in nuclear physics.

Now to the Bangalore period. He was at IISc from 1939 to 1945 and would later say: 'They were six very happy and fruitful years in my life' (Figure 3).

As is well known, he was on holiday in India in 1939 when the Second World War broke out and he could not go back to Europe. In 1940, he joined IISc as 'Special Reader in Theoretical Physics'; and in 1942, he became Professor in the Cosmic Ray Research Unit. At that time, C. V. Raman was Head of the Physics Department. In 1941, Bhabha was elected Fellow of the Indian Academy of Sciences, Bangalore as well as of the Royal Society, London.

In this Bangalore period there was a change in the style, the tenor, of his work; it became distinctly more formal and mathematically oriented. One wonders if it was in part due to being isolated. But we must remember also that he initiated an extensive experimental programme in cosmic ray research in India. There is a historic photograph of him helping send up a payload on a balloon from the Central College quadrangle. Sreekantan was later a part of this effort and has recounted it many times, including in the July 1998 issue of *Resonance*⁶.

In his Bangalore work, the deep influence of Dirac continued. In 1938, Dirac had presented the first logically and mathematically precise relativistic classical point electron theory, later called the Dirac–Lorentz theory. Already in Cambridge in 1939, Bhabha had done further work on this theory, with which Heisenberg had strongly disagreed. This was connected with the divergence problems in quantum electrodynamics. Bhabha had also started work with Corben to extend Dirac's 1938 work to include spin or internal structure for point charges. This continued in Bangalore, and also with Harish Chandra in 1944–1946. His work on wave equations began here in 1945.

But may be again due to isolation, Bhabha could not contribute to the decisive advances in renormalization theory, which finally made quantum electrodynamics the jewel of physics. The first steps had been taken by Weisskopf in Rochester in 1939, in showing that the divergences were milder in the Dirac electron wave equation framework, and



Figure 3. The Bangalore years – the birth of TIFR.

by Kramers' concept of subtraction of infinities. Recall that Abdus Salam – seventeen years younger than Bhabha – was in Cambridge in 1951–1953 at the right time, and made important contributions to the development of renormalization methods.

Bhabha's interests in group theoretical and algebraic methods developed in Bangalore. He was probably influenced by B. S. Madhava Rao of Central College, nine years his senior.

An important event or episode in the Bangalore period was the appearance or advent of Harish Chandra, a story well worth telling. Born in 1923, Harish Chandra completed his M Sc in physics from Allahabad in 1941–1943. He was taught by K. S. Krishnan, and he had studied Dirac's *Principles of Quantum Mechanics*. This made a deep impression upon him. After M Sc, Krishnan sent him to work with Raman at IISc; and because of his mathematical interests, Raman suggested he work with Bhabha. They collaborated for about two years, leading to the papers of 1944–1946 inspired by Dirac's 1938 work.

In 1945, Bhabha and Krishnan recommended Harish Chandra to Dirac as a Ph D student. Just then Dirac had published a remarkable paper on unitary representations of the Lorentz group, a new idea to mathematics. Dirac put Harish Chandra to work on constructing all the irreducible representations of this group, including unitary ones. Harish Chandra solved this problem and obtained his Ph D in 1947.

Jagjit Singh, in his biography of Salam, relates this story⁹: 'Sometime later when Krishnan met Dirac, the first question the latter asked was, which was the Indian University where Harish had learnt the mathematics he knew. Dirac wanted to send some of his pupils there for education. "If so", Krishnan countered, "why did you then drive him to Pauli with your studied reticence on his work?" Dirac is said to have replied that he was too scared to let his critical comments disturb or distort the flow of ideas of a creative mind.'

Later, Harish Chandra decided to switch to mathematics completely, so he was the gift of Bhabha and Dirac to that subject. Throughout his life, Harish Chandra retained a great sense of 'awe and reverence' for Dirac; later these were also 'mixed with a feeling of gratitude and affection'.

For Dirac's 80th birthday, he wrote: 'I have often pondered over the roles of knowledge or experience, on the one hand, and imagination or intuition, on the other, in the process of discovery. I believe that there is a certain fundamental conflict between the two and knowledge, by advocating caution, tends to inhibit the flight of imagination. Therefore a certain naivete, unburdened by conventional wisdom, can sometimes be a positive asset. I regard Dirac's discovery of the relativistic equation of the electron as a shining example of such a case.'

The other important event of Bhabha's Bangalore period was his discovery of his mission in life. M. G. K. Menon says this was 'when he became aware of the role he would play in the development of India'. In 1944, Bhabha wrote: '...in the last two years I have come more and more to the view that provided proper appreciation and financial support are forthcoming it is one's duty to stay in one's own country and build up schools comparable with those that other countries are fortunate in possessing.'

It was then that he conceived of TIFR. At the suggestion of J. R. D. Tata, Bhabha wrote to the Sir Dorab Tata Trust (his uncle's Trust!) and received the support he was seeking. TIFR was born in IISc on 1 June 1945; it functioned there for six months and was taken to Bombay in December 1945.

The TIFR story is very well known and has been recounted in many articles about Bhabha. Physics-wise Bhabha remained active till 1954, then institution-building took up all his time. Thanks to his contacts, a galaxy of great physicists came to TIFR in the early years to give extended courses of lectures. Dirac came in 1954, and the notes were taken by E. C. G. Sudarshan (then E. C. George) and K. K. Gupta. Then Pauli, Wentzel, Gamow, Heitler, Marshak... came. In 1961, Bhabha held a summer school at IISc and Gell Mann and Dalitz lectured.

But Bhabha did not play a significant role in the applications of group theory to particle physics in the 1950s and early 1960s. The strangeness concept of 1953 due to Gell Mann and Nishijima could well have been created by Bhabha, but he was probably isolated. By the time of the parity violation in 1956–1957, and of the 1957 discovery of the $V-A$ structure of weak interactions by Sudarshan and Marshak, Bhabha had given up serious research in physics. In the Sudarshan–

Marshak paper, by the way, the byline for Sudarshan says 'On leave of absence from the TIFR, Bombay, India'.

In his own work, Bhabha displayed deep involvement with special relativity, but as far as I know not general relativity. His family of wave equations are like an echo of the 1930s work of Dirac, Fierz, Pauli, Rarita, Schwinger, Proca, Duffin, Petiau and Kemmer. The word 'orthochronous' for Lorentz transformations preserving the direction of time is due to him, as also (with Kemmer and Pryce) the name 'meson'. In 1938, he had pointed out the graphic display of time dilatation in the apparent increase of lifetime of unstable particles travelling at high speeds. This is in his paper titled 'Nuclear forces, heavy electrons and β -decay' in *Nature* (1938, **141**, 117–118.) (However, it should be mentioned that this manifestation of relativistic time dilatation was also noted at about the same time by Heisenberg, as recounted in his article 'Cosmic radiation and fundamental problems in physics' given in 1975 and published in *Die Naturwissenschaften*, 1976, **63**, 63–67.)

Art, music, poetry and everything else...

Now to some odds and ends. Chandrasekhar and Bhabha overlapped in Cambridge, both being students of Fowler. In 1951, Chandrasekhar visited TIFR, and Bhabha invited him to join in building up the institute. But Raman advised him against it – 'I don't think you should play second fiddle to him'. In 1953, when Bhabha was visiting Fermi at Chicago, he renewed the invitation. Later Chandrasekhar said: 'I didn't take it seriously enough, I suppose... Retrospectively, I'm not absolutely certain that I was right in not pursuing it.'

Chandrasekhar visited TIFR again for a few days in 1961, and you can read about his feelings in Wali's biography¹⁰. Harish Chandra spent part of 1952–1953 in TIFR, but then he left India for good.

Bhabha was a supremely talented person, with exquisitely refined tastes. I remind you of his family background and connections. He was a gifted artist (Figure 4a and b), and as Virendra Singh says, he played an important role in the emergence of the Bombay School of modern Indian painting. He was deeply interested in Western classical music,

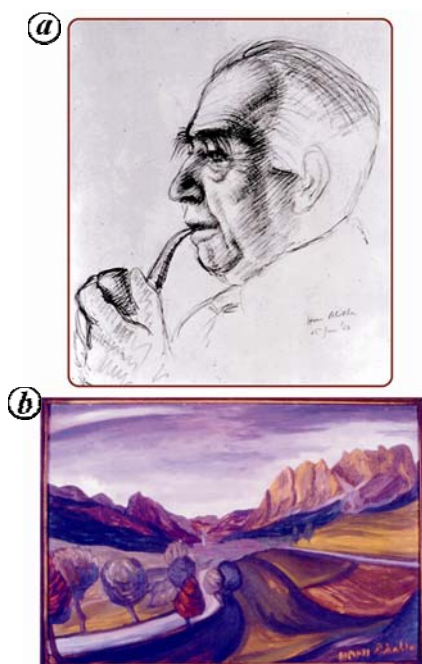


Figure 4. *a*, Bhabha's sketch of Niels Bohr (courtesy: TIFR Archives). *b*, A landscape painting by Homi Bhabha (courtesy: TIFR Archives).

and a perfectionist in all he undertook to do. After listening to a performance of Beethoven's 9th Symphony, he wrote to his brother from Cambridge: 'I was drawn out of myself and raised to sublime heights and my mind hardly got back to work till a long time after the end... It is the sublimest and happiest time I have ever had in my life... Truly, this symphony is the greatest piece of music ever written... The Ninth Symphony is sheer greatness, the sublimest and most colossal achievement of the human mind.' In a letter to a friend, Bhabha said: 'I know quite clearly what I want out of life. Life and my emotions are the only things I am conscious of... Art, music, poetry and everything else that I do have this one purpose – increasing the intensity of my consciousness of life.'

A cat looks at a king

Next to the personal part of this article. As I said at the start, I have gone by the saying – 'a cat may look at a king'. When India gained independence, the Prime Minister of Britain was the Labour leader Clement Attlee. In the House of Commons, Winston Churchill – totally opposed to Indian independence – supposedly said:

'Mr Attlee says he is a modest man. And as we know he has much to be modest about.' So it being understood that I too have much to be modest about, let me say something about my very distant relationship with Bhabha.

In a way he influenced my career and life. After mathematics in college, I joined his Training School in 1958 and was able to change to physics. Then, after two years of study in TIFR, he gave me permission to go abroad to USA for a Ph D. Raja Ramanna was my mentor then, and he told me that on my application for leave Bhabha wrote that I should take up theoretical computer science. Good for that subject that I did not do so. I was on leave of absence for more than six years from TIFR, came back in 1967, and then after five more years in TIFR, I moved here to Bhabha's uncle's institute! My real regret is that he never taught us, he was too far away from us students. Still there are consolations for me. Dirac has always been my source of inspiration, probably this was so for Bhabha too, and certainly so for Sudarshan. So I often think to myself – if Bhabha had seen some of my work, he might have been pleased. Recall the Bhabha–Corben theory of relativistic spinning classical particles. Using Dirac's sublimely beautiful 1949 theory of constrained Hamiltonian dynamics, and knowledge of all continuous subgroups of the Lorentz group, Atre and I were able to give a comprehensive theory of *all possible* classical relativistic point objects with internal structure. This might have made Bhabha happy. With his love for wave equations, he may have liked my proof of the completeness of the solutions of the unitary infinite component Majorana wave equations. With his deep grasp of quantum mechanics, relativity and group theory, he would have been pleased to see what I have done with Wigner's construction of the unitary representations of the Poincaré group, and the studies of the unitary Lorentz group representations taking off from Dirac's and Harish Chandra's work. These are the dreams I sometimes have!

In my college days in Delhi, one of the two radio stations – Delhi B – would play classical Western music four nights a week – 9.30 to 11.00 pm – today this seems unbelievable! So – apart from the expected exposure to classical South Indian music – I was fortunate to be exposed and introduced to this world of

sublime music in Bhabha's words quite early. I also dabbled in art – mainly sketches by pencil but no 'fainting in coils' – but could not keep it up for long. Still, in a portrait of Bhabha at his desk I saw a reproduction of a painting by Renoir, one of my favourites apart from other impressionists and Botticelli. All this must have been action at a very great distance. If I can be regarded as a centi Bhabha and a milli Dirac – or more accurately after renormalization and with greater accuracy in today's terminology, a nano Bhabha and a femto Dirac – I cannot ask for anything more!

A hope for the future

Now to my last point – the 'hope' in my title. As we have seen, after Bhabha realized his mission in life during the Bangalore period, he made a tremendous personal sacrifice – he gave up his own science in order to create a framework and institutions where talented young people could flourish. In his last lecture on 7 January 1966 to ICSU, he said this effort of his did not deplete the universities. I quote: 'It will be seen that this method of building up our staff does not drain away senior persons from the universities, but on the contrary gives training, employment and opportunities to young graduates passing out of the universities.' Spenta Wadia says: '...efforts to partner with the university did not make much progress. B. M. Udgaonkar remembers Bhabha's unsuccessful attempts to modernize the university syllabus, after which he decided to start the Atomic Energy Training School.'

However, Venkataraman remarks: 'One great mistake Bhabha did was to bypass the universities. It might have been expedient to do so at that time, but if there had been more strong men in the universities in the early days, they (the universities) might not have decayed so fast.'

Remember that in the previous era K. S. Krishnan, M. N. Saha, S. N. Bose had all taught and functioned in universities. And as far as I know, in the developed countries of the West, the best universities have retained their pre-eminent positions as centres of research and scholarship even as specialized institutions have appeared. In India, is it not time now to restore the balance? Should

not an attempt be made? Over the past six or seven decades, many generations of young people have benefited from the institutions and structures that Bhabha created just for them. Is it not time that these same persons make a sincere effort to give the universities a helping hand in every conceivable way – at least the better administered and endowed ones to begin with – so that when one thinks of the best research and scholarship in the country, one does not automatically turn to our specialized institutions? This is my hope.

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