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Homi Bhabha—personal reminiscences

Govind Swarup

Homi Bhabha, who died at the rather young age of 56 in an air crash on Mont Blanc on 24 January 1966, was one of the principal architects of modern science in India. His important contributions to theoretical physics and cosmic rays are well known[1]. He was an institution builder *par excellence*. The Tata Institute of Fundamental Research (TIFR) and the Bhabha Atomic Research Centre (BARC) are superb monuments to his scientific and artistic genius. He was also deeply interested in arts, music, literature, architecture and environment. His artistic gifts are embodied in the many fine paintings and pencil portraits he created. As noted by Sir John Cockcroft[1,2], in 1967: 'Human progress has always depended on the achievements of a few individuals of outstanding ability and creativeness. Homi Bhabha was one of them.'

I first met Bhabha during his visit to the National Physical Laboratory (NPL) in New Delhi in 1951. He was actively participating in the launching of an array of balloons for cosmic-ray research. His drive and attention to details were awesome and infectious. In 1955 he visited the Potts Hill Station of CSIRO near Sydney, where many dramatic and remarkable discoveries had been made by Bolton, Christiansen, Kerr, Mills, Wild and others under the leadership of J. L. Pawsey. I had been deputed to work there under a Colombo Plan fellowship by Sir K. S. Krishnan, Director of NPL, who was also my teacher and mentor. Also, R. Parthasarathy was on deputation from the Kodaikanal Observatory. Bhabha's interest in our work and in the field of radio astronomy was most encouraging. I was also excited by Krishnan's letter to me in February 1955 that NPL wanted to start 'some radio astronomy work even with the meagre resources available in the laboratory'. In February 1955 I proposed setting up a '2100-foot-long 32-element interferometer to operate simultaneously at 60-cm and 1.8-m wavelengths' for studying the Sun, using 32 numbers of 1.8-m dishes which Pawsey agreed to transfer to India under the Colombo Plan. A group was formed at NPL in August 1955, but progress was slow since the transfer of the dishes to India got delayed for various reasons. Many of us, including R. Parthasarathy, N. V. G. Sarma, late M. N. Joshi, T. Krishnan and M. R. Kundu (who had joined NPL after obtaining his doctorate in France), went abroad to gain further experience.

In February 1957 Pawsey wrote to me at Harvard: 'If you are returning to India, I should recommend you to place great emphasis on electronics. It is a key to open many doors.' I joined Ron Bracewell at Stanford to pursue my Ph D in radio astronomy. I continued correspondence with Pawsey, Christiansen and Kerr concerning a radio astronomy programme in India. In September 1960 Christiansen wrote to me that several of us who were working abroad 'should get together for a united attack on the monolith of Indian bureaucracy'. An opportunity surfaced when we met at the triennial meeting of the International Astronomical Union at Berkeley, California, in August 1961.

In September 1961 T. Krishnan, M. R. Kundu, T. K. Menon and myself wrote a 'proposal for the formation of a radio astronomy group in India' and sent it to a number of scientists and institutions in India, including Bhabha. Copies of the proposal were also sent to five renowned astronomers, Bok, Denisse, Pawsey, Shapley and Oort, asking them to send their confidential assessments to the concerned organizations in India. The proposal was supported by all of them; for example, in his characteristic way, Bart Bok's recommendation was very generous: 'It seems to me that their offer to return to India as a group is a unique one, and one that should by all means be accepted and acted upon promptly. An offer like the present one comes only rarely in the history of the scientific development of a nation which, scientifically, is obviously coming of age' [letter to Bhabha dated 5 October 1961]. M. G. K. Menon, then Dean, TIFR, forwarded our proposal to Bhabha who was then visiting Geneva. Bhabha promptly cabled us to meet him at Washington, DC in November 1961. After meeting Bhabha, T. K. Menon wrote: 'He talks quite happily of final outlays of 50 to 100 lakhs. Unbelievable for us at present.'

Bhabha's telegram dated 20 January 1962 reads, 'We have decided to establish radio astronomy group stop letter follows with offer.' A prompt action indeed by any standards in the world! T. K. Menon, Kundu and myself accepted the offer. In reply, he wrote to me on 3 April 1962, 'If your group fulfils the expectations we have of it, this could well lead to some very much bigger equipment and work in radio astronomy in India than we foresee at present.'

This development was noted with great interest by other Indian astronomers working abroad. V. Radhakrishnan, then at Caltech, wrote to me on 7 June 1962, 'Do keep me informed of the progress, as it seems inevitable that sooner or later I shall find myself helping you in trying to do radio astronomy in India.'

In the above proposal, we had suggested building a solar radio inter-

Sketch of Niels Bohr by Bhabha

ferometer in the first instance and soon thereafter a large 'Mills Cross' for operation in the metre-wavelength region, in which the sky was relatively unexplored. However, I felt that the capabilities of a Mills Cross for extra-galactic work were somewhat limited. Inspired by Bhabha's encouraging response, and Pawsey's advice to me in October 1960—'with regard to the objectives of such a group . . . keep off the fashionable stuff as far as possible. Be original. Try, if possible, to develop ideas which one or more of you have originated'—, I started thinking of unusual types of instruments for solving specific problems in some frontier areas of radio astronomy. For example I suggested in May 1962 the possibility of constructing in India a parabolic cylinder fixed in the ground, of about 50 ft × 50 ft size, operating at a wavelength of 8 mm, with a steerable array made of a few dozen units of one-dimensional tiltable Hogg-horns of a special design. As it was to operate in a frontier area of the radio spectrum, it would have been a fine instrument!

I joined TIFR in April 1963. The facilities and the general ambience of TIFR were most impressive. I found my

Bhabha and the search for a site for the Ooty Radio Telescope

The unique design of the Ooty Radio Telescope called for a special site, namely a north–south parabolic cylinder (500 m in length) mounted on a hill slope parallel to the spin axis of the earth The cost of earthwork needed for creating such a slope, which, even at the low latitudes of southern India, is about 100 m higher at the north end, would have been prohibitive We had to look for an existing hill slope which would meet our needs It was also important to consider the logistics of access to the site A detailed examination of the Survey of India contour maps showing the hills to the south of Bangalore convinced us that such sites did exist. But could one trust the accuracy of these maps? An accurate survey, by the Survey of India, of these potential sites would have required investment of time and manpower that we could not afford So we decided to take recourse to our own efforts

For finding the proper slope Govind Swarup and I made a series of templates with parallel lines whose spacing corresponded to the contour heights for the required slope for several latitudes These were used to scan all the north–south slopes in the above contour maps for selecting potential sites If the errors in the map are not large, equally spaced contours matching the template would have a fair chance to provide a suitable slope We could then go to the selected sites and determine the slope by a theodolite survey

Being young energetic and slightly foolhardy, we embarked on such an expedition with the aim of checking out 60 sites We took these maps, a theodolite and an experienced multilingual driver, Joseph, with us in a jeep The search, lasting about a month, took us over 3000 km by road to the delightful countryside in the Nilgiris, Kodaikanal and Annamalai hills The hazards of travel through Tamil Nadu during the height of the anti-Hindi agitation did not worry us except when we encountered a slogan-shouting mob which was on the way to set ablaze the Salem railway station. They forced us out of the jeep, but allowed us to proceed since we happily joined them in shouting anti-Hindi slogans, thanks to the advice of our resourceful driver friend Joseph

The summary of our meticulous search was tabulated and presented to Bhabha His first comment was that the competition was like the final four at Wimbledon One was near Kodaikanal Bernard Peters favoured this site as it would have the advantage of sharing library and workshop facilities with Kodaikanal Observatory In Bhabha s judgement these points were not crucial. Choosing a site with potential for expeditious construction and also future expansion into an inter-university centre was more important.

The other three sites were in the Nilgiri hills Bhabha, who had been vacationing in these hills for many years, claimed to know many of these downs and dales quite intimately He saw the importance of the logistics of easy access to Ooty from both the industrial centre of Coimbatore and the academic centre of Bangalore

discussions with Bhabha very stimulating. In June 1963, while reading two papers in *Nature* by Cyril Hazard and Maarten Schmidt concerning 3C 273 in the picturesque setting of the TIFR library, the idea flashed to me[3] that the lunar occultation method could offer an excellent means of measuring the angular sizes of a large number of extragalactic radio sources for distinguishing between the big bang and the steady state models of the Universe, over which there was a raging debate at that time. I made some quick calculations to realize that such an experiment would require a steerable radio telescope with a rather huge area of about 10,000 m^2. For achieving such an area economically, I conceived a novel design of a long cylindrical parabola to be placed along a hill with the same slope in the north–south direction as the latitude of the station, so that celestial radio sources could be tracked for many hours. On the advice of M. G. K. Menon, I set out to write up the above idea.

In August 1963 Bhabha called me for a brief meeting. It was an extraordinary and memorable experience[3]. He soon became quite interested in the proposal, grilled me for a couple of hours, probing in great detail the scientific objectives as well as the structural and mechanical intricacies of the radio telescope, which he could foresee straightaway. Finally, Bhabha gave me the 'go ahead'. On my enquiry concerning the type of project report required, he remarked: 'Young man, do not waste your time writing a project report. Your main problem would be to collect a team. When you have managed that you can submit a project report and proceed with the design and fabrication.'

Bhabha provided us with all the guidance and support needed. To gain experience, we first installed the 32 dishes of 1.8-m diameter obtained from Australia at Kalyan near Bombay. Thanks to the excellent workshop and other facilities of TIFR, they could be set up within a record period of about 18 months and became operational in April 1965. Sarma and Joshi joined us in early 1965. Kundu joined TIFR in 1965, during our formative years, and returned to the US in 1968.

In January 1965 a site was selected for the 530 m × 30 m large cylindrical radio telescope near Ooty. Bhabha's keen interest in this enterprise was very helpful[3] (see box below). Although the Collector of Nilgiris wondered why we were in such a hurry when the life of a star is billions of years, Bhabha got a prompt response from R. Venkataraman, then minister of industries in the Tamil Nadu government (now President of India), and we were allotted the site and electrical power connection within a few months.

On 6 January 1966 Bhabha proposed[4] 'to make this radio telescope one of the centres for inter-university work', for which a 600-acre site was also earmarked by the state government at Ooty. But further progress could not take place because of Bhabha's sudden death two weeks later.

In August 1965, after a detailed evaluation of 17 bidders from India and

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Bhabha, accompanied by M G K. Menon and Bernard Peters, arrived at the Ooty Raj Bhavan from Bangalore heading a retinue of cars provided by both the Karnataka and Tamil Nadu governments The chief engineers of the electricity, irrigation and PWD departments were in attendance The chief secretary to the Tamil Nadu government was also present. B V. Sreekantan and I were already in Ooty I was asked to guide Bhabha to the sites that Govind Swarup and I had short-listed. We began with the Pykara Lake site in Wenlock Downs a picturesque north–south slope just about 500 m long, running right into the beautiful blue water of the lake The slope was bordered by rich clumps of trees On one side of the site there is a small but very prominent Toda village In our earlier visit, a Toda woman had told us that their ancestors had lived on the same grounds from the time of the Mahabharata, tending their *mahishas* (buffaloes) day after day She warned us against any attempts to acquire their ancestral land Six months later, at the time of Bhabha's second visit, they made a ceremonial entrance before the 'court' Bhabha surveyed the land around, appreciated the beauty, inquired about the criticality of north–south alignment and the run of the slope, and gestured to indicate 'not enough elbow room'. A few miles away, across the busy Ooty–Mysore road, about 600 acres of land in a most picturesque valley was identified for an inter-university centre The radio telescope was to become one of the facilities in a larger research organization, which Bhabha planned to have developed around the telescope Bhabha was on the lookout for an institute for the future 'Think big, young man', he exhorted

The second site near Emerald Lake was almost as attractive in terms of setting, but the hill slope was deemed too small Moreover, the site was much further away from Ooty and commuting from the town every day could become a problem

The third site happened to meet all our requirements Fairlawn was a small forest reservation at the edge of Muthorai village. The main north–south slope was associated with additional space where additional antennas could be erected for a radio interferometer. Bhabha, accompanied by Govind Swarup, visited the site once again before the selection was finalized On this visit, Bhabha was confronted by a very colourful delegation of Toda elders, men and women who came to demonstrate before him against the selection of the Wenlock Downs site, led by Ms Evan Weiderman Piljain Piljain's mission was redundant, as we had already selected the Fairlawn site This fact notwithstanding, Bhabha received the delegation in a manner appropriate for royalty and with éclat defused the issue by giving a patient hearing and promising due consideration.

The rest of the story of acquisition and development of the site has been described by Govind Swarup (see 'The story of Ooty Radio Telescope', in '*Pathways in Cosmic Physics*' edited by R Cowsik, Tata McGraw-Hill, Delhi, 1986, pp 349–360)

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abroad. M s Tata Ebasco (now M s Tata Consulting Engineers) were selected to design the Ooty Radio Telescope. They suggested that their design be reviewed by an overseas expert for a fee of $50,000. When Bhabha asked my views, I quipped that in hat case I could have as well continued doing radio astronomy abroad. Bhabha was even more emphatic. He said that even if it takes away our time from scientific research, our efforts for designing the antenna in India would be of great advantage in the long run when 'you want to do bigger things'. Bhabha and M. G. K. Menon suggested forming an antenna group at TIFR, so that it could design large microwave antennas needed in the country for various purposes. A Microwave Antenna System Engineering Group was set up in 1968 in the Department of Atomic Energy with active collaboration of TIFR under the initiative of Vikram Sarabhai, who succeeded Bhabha as Chairman, Atomic Energy Commission. This group (later transferred to the Electronics Corporation of India, ECIL), along with Tata Consulting Engineers, was responsible for the successful indigenous fabrication of the 29.7-m-diameter satellite earth station at Arvi during 1968–70, a notable achievement for India. As a result, India has designed and fabricated most of its microwave antennas indigenously over the last twenty years, their value exceeding Rs 1500 million.

The Ooty Radio Telescope[5] became operational in February 1970, four years after Bhabha's death. As he desired, the telescope was designed indigenously, by a team consisting of Sarma, Joshi, myself and several young talented graduates who joined TIFR during the sixties. T. K. Menon contributed to our efforts during his stay at TIFR from 1970 to 1974. The scientific output of our group over the last twenty-five years is summarized in an accompanying article (see page 79, this issue). The credit for the success of our ventures goes entirely to the close team work by all the concerned staff of TIFR.

The fine infrastructure and organizational set-up of TIFR, which was seeded and carefully nurtured by Homi Bhabha, have enabled us to continue to strive towards excellence over the last twenty-seven years. We look forward to even greater challenges ahead as Bhabha had foreseen (see articles on GMRT, page 95, and on ITRA, page 106, this issue). As Indira Gandhi said[2], 'India will long cherish Homi Bhabha's memory, for he was deeply involved in her destiny and in the processes of changing the texture and quality of her society.'

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2. Cockcroft, J. and Menon, M. G. K., *Homi Jehangir Bhabha with a Foreward by Smt Indira Gandhi*, The Royal Institution of Gt. Britain, London, 1967.
3. Swarup, G., in *Pathways in Cosmic Physics* (ed. Cowsik, R.), Tata-McGraw Hill, Delhi, 1986, p. 349.
4. Bhabha, H. J., *Science*, 1966, **151**, 541.
5. Swarup, G. *et al.*, *Nature Phys. Sci.*, 1971, **230**, 185.

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Govind Swarup

He is the eternal optimist; his enthusiasm is infectious, he roadrollers talented scientists and engineers to work with him and for him, he twists the arms of science administrators into funding his mammoth projects (which for some reason they seem to do with a smile), he is the man with the proverbial one-track mind. This is Govind Swarup who first dreams up and later builds his remarkable radio telescopes.

He could be brutally frank. He built the large dish at Arvi for the Overseas Communication Services (at the suggestion of Vikram Sarabhai) and then when he heard that India was importing the technology again, Swarup said that his blood boiled. 'It is a shame that the second 30-metre Intelsat antenna is being built by Japan as a turnkey project. It is a sad commentary on the electronics companies of India who already possessed the antenna technology.' Again, after his vain attempts to bring back Indian engineers from the US, Swarup said almost in disgust, 'They are only interested in money, all this talk of lack of challenge in India is bunkum, you cannot ask for a greater challenge than GMRT.' One sees here again his one-track mind!

Industry and scientists do require this admonition. But the obvious discomfort he creates is often wiped out by his spontaneous and disarming smile.

Says he: 'It is not easy to work in the field of experimental physics in India. There exists a technological gap which is particularly noticeable if one wishes to work in the frontiers of science, most of our physics students are ill prepared for experimental work due to the lack of facilities in universities, they therefore opt for theoretical studies instead.' But this has not deterred Govind for he has built around himself, wherever he has been, an outstanding experimental group—first at Bombay, then at Ooty, and now in Pune.

In his undergraduate and graduate days Govind was strongly influenced by his teacher, the renowned K. S. Krishnan. Was it this man who injected into Govind Swarup the burning desire to bring radio astronomy into India?

As a fellow at Radio Physics, Sydney, Australia, he came in contact with great pioneers like J. L. Pawsey and W. N. Christiansen, and at Stanford, R. N. Bracewell (his research guide) who greatly influenced his way of thinking.

With this background and the energy and creative spirit that Providence has endowed him with, one can understand why he has succeeded and will continue to succeed.