Atomic State: Big Science in Twentieth-Century India*. Jahnavi Phalkey. Permanent Black, 'Himalayana', Mall Road, Ranikhet Cantt, Ranikhet 263 645. 2013. xvii + 335 pp. Price: Rs 795.

This book by Jahnavi Phalkey tells an absorbing tale of three cities – Bangalore, Calcutta and Bombay – of physicists and institutions in them, and their competing efforts from the late 1930s onwards to initiate research, teaching and training in nuclear physics in India. It was a tumultuous period in Indian and world history, as much as in physics. Nuclear fission had just been discovered. The steps towards India's independence and planning for the future were gathering strength. Soon the Second World War would engulf the world. Towards its end the atom bombs dropped on Hiroshima and Nagasaki in August 1945 demonstrated the awesome power of nuclear weapons, and also how close politics and science had come to one another, on a scale never seen before. After this, the link between nuclear research and politics, weapons and war became inevitable.

To see these events in perspective, it helps to describe briefly the development of the subject of nuclear physics during the decade of the 1930s. The nucleus, the massive central core of the atom, had been discovered much earlier by Ernest Rutherford in 1911. In his atom model, electrons orbited the nucleus but at very great distances, much like planets in the solar system. Subsequent developments – Niels Bohr's 1913 theory of atomic structure and spectral lines, the old quantum theory pursued up to 1922–23, and then the discovery of quantum mechanics proper in the brief period 1925–1927 – were concerned largely with the physics of electrons and radiation. In this process the proper theoretical foundations for chemistry and spectroscopy were created.

In 1917, Rutherford had demonstrated the transmutation of the nucleus of nitrogen to that of oxygen, when bombarded by helium nuclei. Initially it was believed that all nuclei are made up of protons, the nucleus of hydrogen. Then James Chadwick's 1932 discovery of the neutron, as a constituent of atomic nuclei beyond hydrogen, inaugurated the field of nuclear physics proper. It must be recalled here that Bohr had realized much earlier that all three forms of radioactivity are nuclear processes, having nothing to do with the shells of electrons in atoms. Though it was not initially clear, later developments showed that the principles of quantum mechanics were valid at the nuclear as much as at the atomic level.

Soon after 1932, the subject advanced rapidly. On the theoretical front, important ideas came from Werner Heisenberg, Eugene Wigner and Ettore Majorana among others. Bohr too contributed important ideas – the liquid drop model of the nucleus, and the compound nucleus picture of nuclear reactions. On the experimental side, in the mid 1930s Enrico Fermi and his group in Rome showed that irradiation of atomic nuclei by slow neutrons produced new radioactive species. In 1939 Otto Hahn and Fritz Strassmann in Germany made the startling discovery of nuclear fission: again upon irradiation by neutrons, nuclei of uranium split into fragments of comparable sizes, accompanied by release of more neutrons and tremendous amounts of energy. That this nuclear fission process could be a source of energy on a hitherto undreamt of scale was realized quickly by Fermi, Bohr, Wigner and others. This realization led to many historic events connected with the Second World War: the August 1939 letter from Albert Einstein to Franklin D. Roosevelt, President of USA, alerting him to the possibility of a nuclear bomb, the setting up soon after of the Manhattan Project under Julius Robert Oppenheimer's leadership to develop the bomb, and the actual attacks on Hiroshima and Nagasaki on 6 and 9 August 1945 respectively.

In passing it may be mentioned that 'atomic energy' and 'atom bombs' are both misnomers; the correct phrases are 'nuclear energy' and 'nuclear bombs'.

Thus during the 1930s nuclear physics emerged as an important frontier of physics. The study of cosmic rays, and the development of the technology of cyclotrons led by Ernest O. Lawrence at Berkeley, USA, were the other major areas at the frontiers of physics at that time.

It was against this background that in 1938, Chandrasekhara Venkata Raman at the Indian Institute of Science (IISc) in Bangalore, and Meghnad Saha at the University Science College in Calcutta, independently felt that for the progress of physics in India the subject of nuclear physics had to be introduced in our institutions. Saha, Satyendra Nath Bose and Raman were the three stalwarts of Indian physics in the 1920s. Their achievements in 1920, 1924 and 1928 respectively, had placed Indian physics at the forefront of the subject worldwide, with Raman receiving the 1930 Nobel Prize. Raman and Saha were three years apart in age, and relations between them had been difficult from the time that Raman had been in Calcutta. Apart from this, Raman had faced difficulties at IISc to which he had moved from Calcutta as Director in 1933. By 1937 he had been forced to step down from Directorship, but he continued as the Professor of Physics till his retirement in 1948.

At that time in India some areas of science were covered by National Surveys set up by the British – these included botany, zoology and geology. However, subjects like physics, chemistry and mathematics were cultivated mainly in a few university departments and research centres. Among the better known places were the IISc; the Indian Association for the Cultivation of Science (IACS) in Calcutta where Raman worked from 1907 to 1933; the University of Calcutta from where Raman moved to Bangalore in 1933; and the University of Allahabad where Saha had been Professor from 1923 to 1938 before returning to Calcutta.

Both Raman and Saha had research and training of students in mind in their proposed plans. Raman sent his student R. S. Krishnan to the Cavendish Laboratory in Cambridge in 1938 to be specifically trained in nuclear physics. Krishnan completed his Ph D in 1941 and returned to India, to try and carry forward Raman's plans. Similarly, Saha sent his student B. D. Nagchoudhuri to Berkeley in 1938 to be trained directly by the cyclotron pioneer Lawrence. Nagchoudhuri completed his Ph D in 1940 and headed back to work with Saha on his project.

Meanwhile, it was becoming clear in the West that the demands of the subject of nuclear physics were so great that individual universities could not afford to accommodate such programmes on their own. A few medium to large size universities in the US did run cyclotrons on their campuses, but they soon shifted to a collective mode of functioning. For example, the Brookhaven National Laboratory was set up in 1947 as a joint

*This review is co-published with the *Indian Journal of History of Science*, Indian National Science Academy, New Delhi.

venture of several universities in the region. The atomic energy research establishment at Harwell, UK was similar.

The two other important persons in Phalkey's book are Homi Jehangir Bhabha and Shanti Swarup Bhatnagar. Bhabha was about 20 years younger than Raman and Saha, and had been trained in Cambridge in the early 1930s in the modern areas opened up by quantum mechanics. He had done outstanding work on the theoretical analysis of cosmic ray phenomena, and was familiar with the leading physicists and institutions of that period in Europe. While visiting India on a holiday in 1939, the war broke out and he could not return to Europe. He had family connections in Bangalore going back a couple of generations. Raman offered him a position as Reader in Theoretical Physics at IISc in November 1939, elevated to a Professorship in 1942. During the Bangalore period, Bhabha conceived of a new research institute in India similar to those he had been at in Europe. With help from the Tatas, in mid 1945 the Tata Institute of Fundamental Research (TIFR) was formally established, first within IISc, and six months later moved to Bombay.

Soon after, the Atomic Energy Research Committee (AERC) was set up in May 1946, functioning within the Council of Scientific and Industrial Research (CSIR) and with Bhabha as Chairman. In 1948, this was changed to the Atomic Energy Commission of India (AECI). The Department of Atomic Energy (DAE) came into being in 1954. By this time Bhabha had become the acknowledged spokesman and leader for all efforts in the area of nuclear physics in India.

Bhatnagar, on the other hand, was a chemist who was chosen to head CSIR set up in 1942 as part of the war effort. In the period just before and immediately after independence, the closest advisers to Jawaharlal Nehru on science policy matters were Bhatnagar, K. S. Krishnan and Bhabha. Even though Saha had been a part of the planning process in preparation for independence, he was not a member of this circle around Nehru.

With this much background, Phalkey's book and its aims are easily appreciated. The two opening chapters describe science, more particularly physics, in India under British rule, as well as the growth of an Indian scientific community, and discussions on the way in which scientific research supported by Government should be organized post-independence. An important early event was the establishment of the Indian Science Congress Association by Asutosh Mukherjee in 1914. The times were difficult, and people, institutions and resources were limited. This part of the book is of course not limited to nuclear physics. The next three chapters are devoted in turn to Raman's proposal to start nuclear physics activity at IISc, Saha's proposal to do so and to build a cyclotron in Calcutta, and the (slightly later) establishment by Bhabha of TIFR in Bombay, leading on to a full fledged programme of atomic energy research in the country also centred in Bombay. As mentioned earlier, the general consensus developing worldwide at that time was to create centralized shared laboratories for nuclear physics-type activities, collectively 'owned' by several universities. In retrospect, it seems this path was unavoidable in India too.

The Bangalore effort continued till 1947, when it was finally given up. Krishnan prepared and presented plans on three separate occasions – 1942, 1945 and 1947 – to start nuclear physics research and training at IISc, but could not succeed. Possible sharing of facilities among IISc departments was also considered. It is relevant to remember that Krishnan went to Cambridge just before Bhabha came to Bangalore; by that time institutions in the US were going beyond the Cavendish (already depleted due to the war) in nuclear physics. So in that sense Krishnan went to the Cavendish too late, and received limited guidance. After his return to Bangalore, Krishnan, Raman and Bhabha overlapped at IISc for about four years. The final 'fatal' report on the Krishnan proposal was written in 1947 by Bhabha and H. J. Taylor of Wilson College in Bombay. Even though the Raman–Krishnan proposal was quite modest compared to the Calcutta proposal and the efforts in Bombay, the report viewed it as not in consonance with national-level policies for nuclear physics research. Actually it turned out that Raman and Krishnan had underestimated the support needed to establish nuclear physics research at IISc. At one point Raman wrote to the Government of India complaining that the AERC wanted to 'create a monopoly in the subject for certain favoured laboratories and individuals to the exclusion of others'. All these events are described and analysed in great detail by Phalkey. Bhabha even invited Krishnan to move to TIFR and pursue his ideas there, but Krishnan declined. He succeeded Raman as head of the Physics Department at IISc in 1948, and switched to other areas of research.

The story of the Calcutta effort is somewhat more complex. Saha was in close contact with Lawrence for a long time, and sought his help and advice on many matters. He was involved earlier with the national planning effort, and was close to the Congress party and later became Member of Parliament. He and Nagchoudhuri introduced teaching of nuclear physics in Calcutta, and after many years of struggle built a cyclotron in 1954. Along the way Saha saw the need to move nuclear physics activity outside the university, and founded the Institute of Nuclear Physics in 1948. (This was later renamed as the Saha Institute of Nuclear Physics; SINP). There were several occasions when problems arose with Bhabha and the AEC. It comes as a surprise to read that for practical travel-related reasons, Saha could not attend many critical meetings convened by Bhabha. In important ways it turned out that Bhabha was more practical minded than Saha. On one occasion Saha wrote a bitter letter to Nehru recalling their association since 1936, and then complaining against his being ignored. There was even an episode which can be viewed as Bhabha 'snubbing' Saha and his group. By 1946–48, Bhabha and Bhatnagar were acknowledged as the leaders of science in India, while in comparison Saha was reduced to a minor figure. Finally, in the end, where the Bangalore effort failed, the one at Calcutta succeeded, at least partially. As Phalkey mentions in a footnote, 'the laboratory in Calcutta… was the only laboratory for nuclear physics that survived the struggle against centralization and grew steadily in importance…'.

The chapter on TIFR and the emergence of the atomic energy programme and establishment is interesting for its own reasons. In contrast to Raman and Saha, Bhabha had broader aims than the pursuit of nuclear physics alone: his interests included the physics of elementary particles as well as studies of cosmic rays. Bhabha was indeed very close to Nehru, who supported him in all his major plans. In 1946, TIFR was named an institution 'of national importance' by the AERC. Bhabha simultaneously led

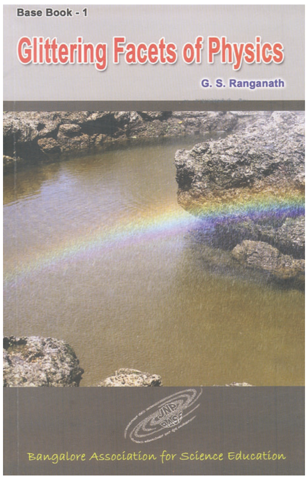
TIFR – the 'cradle of the atomic energy programme' – as a centre dedicated to pure research, and the Atomic Energy Establishment (AEE) as a mission-oriented organization. In Mark Oliphant's words, he built one around individuals and the other around tasks. Even so, there were ambiguities in the relationship, leading to difficult situations and decisions involving the two. Even within TIFR, we read, there were changes of policy and directions which seemed unavoidable, but led to some bitterness. It is a tragedy that Bhabha died in an air crash in 1966, when he was not yet 57; one feels somehow sure that he would have handled these 'problems', and continued to provide leadership, imaginatively.

To sum up, Phalkey has written a very well-researched book on the emergence of nuclear physics as a research field in India during a crucial phase of our history. There are numerous footnotes and references in each chapter rounding out an absorbing account. It seems that no other area in science – neither chemistry nor biology – lends itself to such a study and all the lessons it teaches us. In a way this book reminds us of Constance Reid's acclaimed biography of David Hilbert, in that Reid was not a professional mathematician and yet wrote so well.

This account may well lead us to revise our views of several leading figures in our science in the past. Many decades have passed since those times, so we should view individuals and events dispassionately. It will be of enormous interest to all those associated with or working in IISc, SINP, TIFR, DAE and CSIR today, not to speak of the wider scientific community of the country. We should not ignore history, but we should not feel trapped by it. We need to learn from it and move on.

N. MUKUNDA

 # 103, 6th Main Road,
Malleswaram,
Bangalore 560 003, India
e-mail: nmukunda@gmail.com



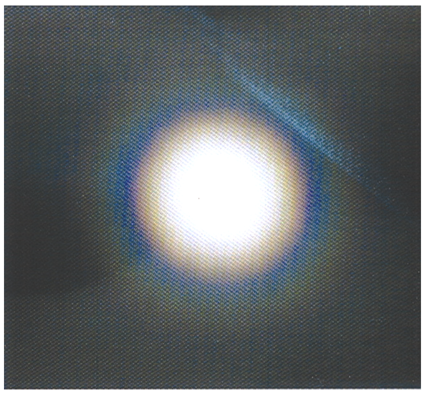
Glittering Facets of Physics. G. S. Ranganath. Bangalore Association for Science Education, Jawaharlal Nehru Planetarium, T. Chowdaiah Road, High Grounds, Bangalore 560 001. 2014. 152 pp. Price: Rs 100.

This book is the first of a promised series to be brought out by BASE – the Bangalore Association for Science Education. Typing these four letters into a *Google* window will bring up a well-known chain of coaching classes for competitive exams leading to professional education. This lesser known BASE has, in a sense, been doing the opposite for more than two decades – exposing school students to science in a manner based on discussion and activity, at the Jawaharlal Nehru Planetarium, which it oversees. G. S. Ranganath has given many lectures on classical topics in physics in this forum, which have been greatly appreciated by his students over the years. It is not surprising that there was a strong feeling that they should reach a wider audience in book form.

I do not know of another physics book quite like this one, perhaps best described as a roller coaster ride through a wide range of classical topics – the solar system, laws of motion, electromagnetism, light and the Earth. The chapters do not teach in a conventional sense – they expose, excite, enthuse, encourage. The comments and explanations are terse and the transitions can sometimes be abrupt – but in what other book would one move from sharks to alligators to head injuries to glass chimneys around kerosene lamps, in the span of four pages? The choice of material and sequence is uniquely the author's own. And the glittering facets go beyond what is conventionally regarded as physics – there is a soft corner for the living world which shows through. For example, the reader can contemplate the ratio of bone to total mass of multiple species, and learn what it tells us.

This is not one of those books which talk down to children. In fact, my guess is that it may be a challenging starting point for the average student, but will certainly cater to the strongly motivated ones, and should be a valuable resource for their teachers. Given that most of the topics covered are part of the standard XII syllabus, this kind of material will be a breath of fresh air in classrooms made dreary by routine drill, oriented towards competitive exams. Even hardened physicists like this reviewer will find gems to take away – I did not know that Cavendish performed his experiment on an apparatus inherited from John Michell (who has priority over Laplace regarding the black hole idea), or that many people had dropped weights from towers before Galileo allegedly did so. The electric bell and electric motor are common places of high-school education, but the purely electric (i.e. no magnetic fields) bell and motors were a revelation to me.

History is given its due. It covers not just the standard heroes – Newton, Galileo – but even school children who came up with brilliant ideas – have you heard of Laura Drew or Vincent Converse? The rapid guided tour of concepts, applications and connections remains the major feature of this book. One concern is that it does not seem to have the backing of a publisher. Organizations like BASE are usually not geared to the strategies of the book trade. One hopes that word of mouth and reviews will help the book find the audience that it richly deserves. A second printing can address some



Corona due to pollen grains