Soma Banerjee has provided a thoughtful and sensitive account of Meghnad Saha as a physicist and nationalist in India and his rise to international fame as an astrophysicist. I have a large collection of letters, given to me by Saha's family, between him and other scientists and between other scientists about him. I wanted to share some of the insights and knowledge I gathered from those letters and from other publications.

The notion persisted that Saha owed the idea of his groundbreaking work in astrophysics, the Saha equation, to Alfred Fowler, with whom he worked in England in 1920. Saha was particularly offended by a talk in 1946 in which Harry Plaskett discussed Saha's work on the thermal ionization theory. Saha found the discussion "entirely gratuitous and misleading" and wrote Plaskett a long letter discussing how and where the ionization theory was developed and describing his career in India. Plaskett's response was remarkable:

> What was quite new to me was the fact that the early part of your work had been done in India, not Germany, before you came to Fowler's laboratory. The knowledge that you had done so much without help and backing in India only serves to increase the admiration I have always felt for your great contribution to astrophysics. I only regret that I did not know about this at the time of my presidential address, and can only ascribe my ignorance to a probably incorrectly remembered statement of [Henry Norris] Russell on his return from England in the early 1920's. . . . Your place in the history of astrophysics is secured for all time. So much so indeed, that it seemed to me worthwhile to correct a tendency (prevalent in some quarters of the United States) to regard astrophysics stemming from the work of [William] Pickering and yourself, forgetting the indispensable contributions from [Ralph] Fowler and [Norman] Lockyer.

At the Calcutta School of Physics, Saha belonged to a generation of stellar physicists[1] that included Jagadish Bose, a pioneer of radio-wave communication, semiconductor junctions, and plant biophysics; Chandrasekhara Venkata Raman and Kariamanickam Srinivasa Krishnan, who also made major contributions to the discovery of the Raman effect;[2] and Satyendra Nath Bose of Bose–Einstein statistics, Bose–Einstein condensation, and bosons. That group emerged quickly in an almost barren field that had not yet produced internationally acclaimed scientists. Subrahmanyan Chandrasekhar, according to a biography by Kameshwar Wali, speculated that this remarkable assembly was probably associated "with the need for self-expression, which became a dominant motive among the young during the national movement. . . . We could show the West in their own realm that we were equal to them."[3]

The nationalistic spirit surely had played a major role in the emergence of that extraordinary group, but somehow the city of Calcutta was also fortunate to have visionaries and mentors like distinguished mathematician Asutosh Mukherjee, who was also a judge of the Calcutta High Court and later a vice chancellor of the University of Calcutta, and Prafulla Chandra Ray, a distinguished chemist and industrialist. Both were able to identify talents among the younger generation and tried to provide them with a nurturing environment and as much support as possible.

The Saha and S. N. Bose translation of the relativity papers of Albert Einstein and Hermann Minkowski in 1919, which represents the first translation of those papers, grew out of a program of self-study of relativity and quantum mechanics. Mukherjee, then vice chancellor, mandated that work for the newly hired young lecturers in the university so they could teach the new subjects to their students (see PHYSICS TODAY, September 2006, page 10). Saha and Bose were relieved of any teaching responsibility in their first year. Both the Saha equation and Bose–Einstein statistics followed soon after the self-study and marked the birth of theoretical physics research in India. Scientific research in India received very little financial or infrastructural support at the time of Saha and the others. Saha struggled to generate modest funding from different courses, including the US, but without much success.

In addition to his prolific scientific contributions, Saha also led various organizational aspects and coordination of scientific work in India. Chandrasekhar, then a student at Cambridge University, characterized those efforts as "beyond all praise"; he sought Saha's help for the release of Pyotr Kapitsa from his native country, the Soviet Union.

Later in his career, Saha got involved in national politics, as he thought he must put his knowledge of science to use in contributing to society. Although born into a Hindu family, his activism put him on a collision course with some Hindu religious leaders.

Meghnad Saha was twice nominated for the Nobel Prize by Arthur Compton, in 1937 and in 1940, but without success.

References

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2. K. C. Wali, *Chandra: A Biography of S. Chandrasekhar*, U. Chicago Press (1992), p. 250.
3. Ref. 2, p. 246.

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Science is indeed special

This letter is in response to Charles Day's editorial "Science is special" (PHYSICS TODAY, July 2016, page 8). Obviously, there is an objective truth regarding the universe that exists external to the human mind. However, all of our scientific theories are products of the human mind and therefore not the same as the real universe. To what extent is the progress of science discovering the truth about the universe, and to what extent are humans simply inventing new theories to match current observation? It is human nature to want to believe that our theories are true, so in the debate over discovering versus inventing, our impulse is to skew in the direction of claiming that we are discovering something that was true before we discovered it.

In his book *Constructing Quarks: A Sociological History of Particle Physics* (University of Chicago Press, 1984), Andrew Pickering discusses the flaw in this way of looking at the history of science. Obviously, we discover individual facts that are objectively true, but is our entire view of the universe, based on our current scientific theories, true? Is it even close?

Throughout history, scientists have assumed that their view of the universe was close to being true. Each time, they were proven wrong. It is probably equally wrong to make the same assumption today. We can't even assume that we are making substantial progress toward knowing the truth about the universe, because we don't know how far our current theories are from the truth. Our progress to date might be negligible compared with the distance we have yet to go. However, we can measure the extent to which our present theories explain what we can currently examine. We observe natural phenomena, try to fit them into the framework of current theories, and try to think up explanations for them. Making new observations leads to new theories, which leads to technological advancements, which are applied to building new experimental tools, which enable us to observe natural phenomena that we could not detect previously, which means we have to revise our theories. The process continues in a never-ending feedback loop.

Let me pose a question: Can you arrive at the truth by a method other than science? My answer: That depends on what you mean by "science." We consider Western science to be motivated by natural philosophy going back to the ancient Greeks, which includes a framework of logical reasoning and the scientific method. That approach has been very successful. However, for centuries, the Chinese were able to make scientific progress without that Western tradition, which proves that it is possible, even though their science later stagnated compared with the West's.

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In his July 2016 editorial, Charles Day asks readers to imagine what extraterrestrial science might look like. Here's my response:

Planet Q is cold and dark by our standards, but it is teeming with life. Its inhabitants are microscopic; so small, in fact, that their tiny eyes can see one photon at a time. With their hands they can feel a single atom. They experience a world of quantum jumps, where nothing is gradual or smooth. They do not think of time as a continuously flowing quantity because the only way they can detect its passage is through some kind of change, and all the changes they see are spontaneous and unpredictable. For them, time lurches forward in fits and starts.

Their advanced understanding of quantum mechanics has enabled them to produce sophisticated technology—what we would call nanotechnology. But their science is based on discrete mathematics and number theory; they would be puzzled by our concept of a smooth, differentiable curve. They would be surprised to learn about our Schrödinger equation because it leaves out the quantum jump, the most prominent feature of the physical world.

It would be hard to convince the inhabitants of Planet Q that such things as electromagnetic waves exist, although, of course, they have analogues of diffraction and interference in their own equations. It would be like telling a couple of ants crawling across a pointillistic painting that they are actually standing on a drawing of an umbrella. That would seem unnecessarily abstract to them: Why would you group together those dots and call them something else? If you understand photons, you have no need of an electromagnetic field.

And the residents of Planet Q really would not recognize our ray optics. Even terrestrial physicists agree that such a thing as a light ray does not exist, yet they nevertheless calculate its displacement and direction as it goes through a lens. Earth-bound scientists might patiently explain that the light ray is a convenient fiction, a calculational tool; however, the beings from planet Q have brains that work like quantum computers, so they have no need of such mental crutches.

By contrast, the Shadow people are unimaginably large, each blood cell larger than a solar system, their bodies the size of a galaxy. They move slowly, think slowly, and pay no attention to us. Their physics describes their kind of matter, dark matter, and does not include any details about our familiar electrons, protons, and neutrons, since they hardly interact with those particles.

Zooming out from our galaxy, we see our whole universe, and then a myriad of other universes, coming into existence and expanding like the bubbles in a pot