Science in the Limelight: A Sociological Perspective

After the Breakthrough: The Emergence of High-Temperature Superconductivity as a Research Field

Helga Nowotny and Ulrike Felt
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Reviewed by Simon Foner

By 1986 the cold war was winding down and funding of science by government and industry was decreasing. The discovery of high-temperature superconductors unleashed an unprecedented worldwide outpouring of multidisciplinary activities and pressures for increased funding. The continuous drumbeat of daily news reports promising major new industrial markets produced additional pressures. The intense activity during this period created an ideal arena for a sociological study of the way science is now done, promoted and perceived.

In *After the Breakthrough*, social scientists Helga Nowotny and Ulrike Felt examine what happened during this unusual period of research activity, analyzing the responses of different sectors of the scientific and policy-making enterprise to the discovery of high-temperature superconductivity. They describe the scientists and their collaborations, the building of science policy around institutional complexes of universities, industry and national research centers, the drawing of new actors into the enterprise, the development of national programs to support the expanded efforts, the responses of funding agencies to the pressures and the influence of the news media. The general question they address is, What does the case of HTS reveal about the present state of the science establishment?

The authors' analysis is based on 70 interviews conducted during 1988–89 with university researchers, science administrators and representatives of funding bodies and industry. They visited selected enterprises in Switzerland, Germany and Austria in 1988–89, and in 1990 they extended their observations to The Netherlands. In addition, they attended a 1989 HTS meeting at Stanford University and spent a week each in a Swiss, German and Austrian laboratory to record impressions on working conditions, communication mechanisms and everyday problems faced by the researchers. The authors also used extensive news sources and publications.

In early chapters Nowotny and Felt set the stage for the discovery of HTS and give a snapshot of the activities and game-playing during the euphoric phase in which key players fought to establish their priority claims. Then they describe the quite different operating modes of institutions in Japan, the US, the UK, Germany, The Netherlands, Switzerland and Austria as well as the institutional responses to the demands of the researchers.

As might be expected, those countries that had ongoing programs and infrastructure in low-T_c superconductors responded in a more coordinated way. The scientists sold HTS to the funding agencies with the promise of economically significant technological applications. Various ways to involve industries gave mixed results. The authors also include a provocative chapter on the influence of the news media in the selling of the "HTS story" and the growing influence of the media in science policy.

For instance, the US media gave HTS the most coverage over the longest period, hyped unrealistic changes in technologies and markets, elevated a few scientists to hero status, regularly presented the enterprise in terms of a race or competition with other nations or among scientists and offered a route to rapid scientific publication by press release. In contrast, the European media treated the scientists impersonally and tended to stick to the facts.

In several places, the authors use the word "collusion" to describe the interactions among scientists, funding entities and the media. This word may be too strong. Those involved in conventional superconductor applications could project, soberly, that development of the new superconductors would take many years and, even then, some of the projected economic benefits were fanciful, but their views were either not heard or were ignored. And a lack of understanding of practical applications among discussants was endemic. For example, the myth that superconducting transmission will save enormous amounts of energy persists. As late as 1994, during a plenary talk at the Applied Superconductivity Conference in Boston, I asked an audience of about a thousand how much energy is lost along a 500-mile high-voltage overhead transmission line by normal conductors. Most of the audience of physicists, engineers and materials scientists guessed a 20 to 30% loss. The answer is about 3%!

This book is a case study that will be of long-term value to scientists, science policy makers and those interested in understanding how their interactions with the media and public have changed.

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Perils of a Restless Planet: Scientific Perspectives on Natural Disasters

Ernest Zebrowski Jr
Cambridge U. P., New York, 1997. 306 pp. $24.95 hc
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Human power pales compared to that of the forces of nature. In his fascinating and eminently readable *Perils of a Restless Planet*, Ernest Zebrowski explores human ability to hold Nature in abeyance for a time, but not forever.

Zebrowski provides many wonderful descriptions of the power of nature. He writes about wave-related earthquakes and tsunamis, wind-induced hurricanes and tornadoes and extraterrestrial asteroid events. He shows how unplanned population growth can despoil natural life-support systems. He is a physicist throughout; his accounts are framed by his skilled discussion of the power of the scientific method.

The book's third chapter, "Hazards of Shelter," establishes a mood for what follows by comparing the death tolls from two earthquakes: the one in Messina, Italy, in 1908 that killed 150 000 people and the 1906 San Francisco earthquake, which was more powerful but which killed fewer than 700. The difference stemmed from the resilience of San Francisco's wooden structures, in contrast to the inability of Messina's stone buildings to withstand tensile forces. These examples lead Zebrowski to some nice science, exploring the way elastic limits vary with material and differ enormously and critically in compression and tension, and the ways in which engineers and designers can make use of these technical characteristics. Roman arches like the Pont du Garde, which maintains stone in compression, have been stable for millennia.

Dams are analogous to bridges, but their load bearings are horizontal instead of vertical. An eroding dam can collapse catastrophically, as did an earth-fill dam on the Conemaugh River at Johnstown, Pennsylvania on 31 May 1889—the largest dam failure in the history of the US. In this case, Zebrowksi places blame: The Johnstown flood stemmed from maintenance failure by a private country club owned by captains of industry. They and other wealthy owners contributed little to recovery from the disaster. As Zebrowski puts it, they "were not necessarily evil people" but were "uninformed, and, through their insularity, uninformable." We often see similar behavior today.

Resource depletion can convert a paradise to a wasteland. This occurred on Easter Island, which was a lush, subtropical paradise prior to the 15th century. Polynesian immigrants who arrived then are best remembered for some 200 massive stone statues erected around the island. Less well known is that they found abundant resources but, within 200 years, the forests had been cut and many indigenous animal species hunted to extinction. Destitution, cannibalism and population collapse followed. As Zebrowski puts it: "When people begin eating each other's relatives, they are much less likely to cooperate in solving mutual problems." Does Easter Island offer lessons for us today? It's an example we should ponder.

Perils of a Restless Planet ends with an exploration of the limits of science. Zebrowski uses chaos theory and Edward M. Lorenz's classic 1972 question, "Does the flap of a butterfly's wing in Brazil set off a tornado in Texas?" to warn us that even the best engineering is ultimately powerless against the forces of nature. On million-year time scales, such globally catastrophic events as large asteroid impacts become likely. On the vastly shorter scale of human lifetimes, however, engineering can do a lot.

Perils of a Restless Planet is exciting reading. It would be superb for a lower-division course emphasizing the methodologies of science and engineering, the importance of humility in the face of natural powers and the value of good design. The spirit is similar to that of John McPhee's classic, *The Control of Nature* (Farrar, Strauss and Giraux, 1989), with its many examples of the strength of nature and the problems people have had in trying to tame it. As with McPhee, I read Zebrowski in a single sitting. Students, I expect, will read far ahead of their assignments.

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The Life of the Cosmos

Lee Smolin
Oxford U. P., New York, 1997.
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One of the burdens faced by cosmology is that scientists instinctively recoil from theories designed to explain single, unique events. We live in one universe, and if there are others, our present theoretical framework offers no possibility of observing them.

Nonetheless, a few cosmologists have contrived systems that require or imply the existence of many universes. Lee Smolin is one of these, and in *The Life of the Cosmos*, he presents his scheme in a way that should render it accessible to a very well-educated neophyte and certainly to an undergraduate physics major.

One cosmology that suggests the existence of many universes rests on the anthropic principle, which notes that in their current state of development our fundamental theories contain roughly a score of apparently free parameters. It is not hard to show that some of these cannot be changed significantly without creating a universe in which the kind of life we know would be impossible. In an appendix, Smolin estimates that the probability that a random choice of parameters will lead to a universe at least as hospitable to life as ours is on the order of one in 10^{229}. Thus the anthropic principle implies either a miraculous setting of parameters (by a deity, for example) or that ours is a rare jewel among many barren universes.

Smolin offers a new scheme, one that makes universes like ours commonplace because they are the successful products of a process of evolution. His argument rests on three audacious conjectures. One is that when a suitable theory of quantum gravity is established, the singularity inside a black hole will prove to be the germ of a new universe. The second is that the new universe will have free parameters that are close but not identical to those of its parent. The third is that conditions favorable to formation of large numbers of black holes are also favorable to the existence of life. The scheme, of course, requires that future theoretical developments not significantly reduce the set of free parameters.

The first two conjectures provide the "variable reproductive success" on which a Darwinian process of evolution must rest. The third allows life to come along for the ride. Starting from a universe with randomly chosen parameters, there begins a random walk through parameter space. Initially, early universes will be far from optimum and will die in roughly a Planck time (10^{-43} s). Eventually, a universe will be reached that allows the formation of stars large enough to collapse into black holes. Since each black hole gives rise to a new universe, it can now produce multiple offspring. Thus, reality comes to be dominated by a plethora of near-optimum universes, one of which of course is our own.

Smolin suggests that his scheme can be tested by showing, parameter by parameter, that each near-optimum universe is optimized for black-hole formation and also favors the existence of life. He offers examples of such analyses. For instance, the existence of large amounts of carbon in our universe, which is essential to life, also allows the formation of the cool, near-opaque clouds in which stars, the precursors of black holes, can form. Carbon formation is highly sensitive to the masses of the light fermions as well as to the strengths of the strong and electromagnetic fields. Of course, to obtain meaningful analyses for a wide range of parameters would require an extensive school of theorists working on the problem, so Smolin faces a bit of a challenge of salesmanship.

This idea is interesting, in part because it is "falsifiable," in Karl Popper's sense of the word: If one can exhibit a set of parameters that leads to a universe with more black hole formation than in our own, but that is inhospitable to life, the scheme loses its appeal. Smolin briefly examines several failed efforts of this sort, but given our ignorance about star formation, especially in the early universe, one can hardly rule out such a scenario. Personally, I find a coincidence between black holes and life a bit too miracu-