The “alien spirit” of relativity FREE

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of their identity—is not just applicable to reaching black women, and it is a perspective I continue to keep foremost in mind after having left Spelman (for the record, because the administrators no longer value perspectives such as mine). It has become a part of my view of the culture of physics.

You may regard this as a friend-of-the-court brief, though obviously I have no idea how to do that properly.

Reference

1. K. Dunbar, in *The Nature of Insight*, R. J. Sternberg, J. E. Davidson, eds., MIT Press (1995), p. 365; *J. App. Dev. Psychol.* **21**, 49 (2000).

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The Supreme Court case *Fisher v. University of Texas at Austin* has once again exposed the unresolved problem of race in America. Particularly telling were the comments of Chief Justice John Roberts and Justice Antonin Scalia. Roberts asked, "What unique perspective does a minority student bring to a physics class?" And Scalia said, "Most of the black scientists in this country don't come from schools like the University of Texas." In case that was not sufficiently inflammatory, he continued unfazed: "They come from lesser schools where they do not feel that they're . . . being pushed ahead in . . . classes that are too . . . fast for them."

What Roberts has overlooked is that many of the most brilliant physicists, particularly the theorists, have been outsiders, at least in thought. Their "minority" perspective played a critical role in their success. In physics research, being an outsider can be an advantage when seeking answers to unsolved problems. Of course, being an ethnic or racial minority does not automatically make one a minority thinker. But it does come with unique experiences that could yield remarkable success in research.

The value of outsider thinking is quite clear when one considers how physics advances. For the most part, undergraduate physics education focuses on a codified set of solved problems. Research, on the other hand, exposes students to the unknown. The skills to excel at the latter have little to do with those required for whizzing through the former. Physics departments are replete with examples of problem-set whizzes who floundered in research. The ability to come up with new ideas that inform unsolved problems is a key factor in determining success in research.

The building blocks of modern physics as we know it—quantum mechanics, field theory, and general relativity, for example—all arose from individuals who stepped outside the established line of reasoning. That spirit is exemplified by Howard Georgi and Sheldon Glashow in their immensely influential 1974 grand unification paper, which contains the disclaimer, "Our hypotheses may be wrong and our speculations idle, but the uniqueness and simplicity of our scheme are reasons enough that it be taken seriously." Such a frank admission of the risk involved in doing physics is rare.

A key element that determines a person's ability to make such leaps is the comfort level with being different—even iconoclastic. Minorities are by definition outside the majority culture. Hence, taking risks that would set us further apart from our peers does not feel unnatural. That is, it is easiest to go against the grain when you are not part of the grain!

The outsider status can be used as a great motivating factor to beat the system. Consider, for example, the 1965 physics Nobel laureate and boyhood genius Julian Schwinger. The jacket of Schwinger's 1970 book *Particles, Sources, and Fields* (Addison-Wesley) begins with the quip, "If you can't join 'em, beat 'em." Clearly his outsider status was heartfelt. The 1905 physics Nobel laureate Philipp Lenard, well-known as an anti-Semite, denounced relativity as being derived from an "alien spirit" and dubbed the whole of Albert Einstein's work as part of a "Jewish fraud." Undoubtedly what Lenard recognized, in a through-the-looking-glass way, is that Einstein's minority or outsider status may have been the very thing that enabled him to construct the most brilliant and important theory in physics to date. The "alien spirit" that catalyzed Einstein's derivation of relativity may be the very same outside-the-box mindset that illuminates the thinking of at least some minority theoretical physicists today.

So to answer Roberts's question, central to advancing physics is the ability to be an outsider. For minority physicists, a tendency toward outsider thinking is not fabricated. It is part of who we are, and it is the very thing that is unique to our experience.

It's now 2016, and we have a black president, yet those uninformed comments come from people who are supposed to be the top legal minds in the country. At the very center of what should be a prudent, deliberate consideration of delicate legal matters that affect millions of lives, we find instead insensitive stereotypes that can only detract from the ultimate goal of justice.

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John Bell, relativistic causality, and the arrow of time

Reinhold Bertlmann's reminiscences of John Bell (Physics Today, July 2015, page 40) are a pleasure to read and faithfully summarize the generally accepted wisdom on the topic. However, the article ends at a seemingly insurmountable theoretical impasse: the conclusions of Bell's 1980 review describing the apparent incompatibility of quantum correlations with Lorentz invariance. It would perhaps be preferable to conclude on a more optimistic note, by emphasizing the tacit underlying assumption—the causal arrow of time. After all, the quantum correlations are incompatible not with Lorentz invariance per se but with relativistic causality, a time-asymmetric notion. The culprit, apparently, is in the manner that time asymmetry is introduced into the context of a microscopic theory.

Bell himself fully acknowledged the relevance of causality in his 1990 review of the topic,[1] though he remained unwilling to consider the alternative of retrocausation. He clarified that the "locality" of local realism is merely shorthand for "local causality." In his concluding paragraph he wrote, "The more closely one looks at the fundamental laws of physics the less one sees of the laws of thermodynamics. The increase of entropy emerges only for large complicated systems, in an approximation depending on 'largeness' and 'complexity.' Could it be that causal structure emerges only in something like a 'thermodynamic' approximation, where the notions 'measurement' and 'external field' become legitimate approximations?" That is the question Bell left us with.

Is there hope for a more palatable theoretical description?[1] Bell's theorem tells us that it would require either abandoning local causality or abandoning the causal arrow of time altogether, perhaps replacing it with a weaker temporal arrow, an arrow of information or entropy. At the level of a simplistic toy model, an explicit retrocausal (but otherwise local) formulation can reproduce Bell-type correlations.[2] The challenge remains to formulate a general retrocausal and spacetime-local description of quantum phenomena. Such a reformulation of quantum theory, if achieved, is likely to have important ramifications, perhaps comparable to those following from Feynman's development of path integrals.

References

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2. N. Argaman, *Am. J. Phys.* **78**, 1007 (2010).

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▶ **Bertlmann replies:** In analyzing Bell's theorem, Nathan Argaman emphasizes the tacitly assumed time asymmetry, which becomes the "culprit" in the context of a microscopic theory. John Bell certainly was aware of retrocausal formulations, where the causal arrow of time was abandoned, but he did not consider them as alternatives to local hidden-variable theories. The reason was simply that Bell, like Albert Einstein, did not accept the possibility that an effect might happen before the cause.

Sticking to his "no signals faster than light" idea, Bell demonstrated that ordinary quantum mechanics is not locally causal. We have to accept that nonlocal structure of quantum mechanics, which is experienced in nature.

In Argaman's retrocausal model, the propagation of information from the apparatus backward in time to the source is allowed, and thus no instantaneous action at a distance is needed. Therefore, Argaman may conclude that Einstein's spooky action occurs in the past rather than at a distance.

Since the variables, carrying information that has propagated into the past, must not be accessible on a macroscopic level, doesn't Argaman's retrocausal model just shift the problem from "nonlocality" to the arrow of time? Nevertheless, it is an interesting interpretation of an experiment like Einstein-Podolsky-Rosen and Bell.

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