vector in Sommerfeld's solution. The third was the recognition that those trajectories are the wave-physics counterparts of the rays of geometrical objects—an insight transferred from the analogous phase-gradient trajectories of quantum waves, as envisaged in Erwin Madelung's hydrodynamic picture or the equivalent de Broglie–Bohm representation.

Did Newton "prediscover" that ray-like representation of wave physics? Of course not, but Whig history enables us to recognize it as a prescient groping toward our modern insight—surely a legitimate way of engaging with our discipline's past.

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I read with great interest Matt Stanley's article on why physicists should study the history of their subject and how that history is important to physics education. I fully concur with his statement that one of the most valuable lessons from the history of science is to learn how the concepts of physics were discovered.

Unfortunately, authors of physics textbooks often make up convenient stories about the development of physics, which then are repeated endlessly. For example, one of the most important concepts in physics was Max Planck's introduction of energy discreteness in atomic physics, which led to the development of quantum mechanics. The tale in most textbooks is that he was concerned about the UV catastrophe encountered by the application of the equipartition theorem to the electromagnetic theory of light. But there is no evidence that Planck was aware of the problem, first pointed out by Lord Rayleigh. The actual origin of Planck's fundamental new physical concept is quite different and much more interesting. He found the idea of energy discreteness in Ludwig Boltzmann's 1877 seminal paper on statistical mechanics, where it was introduced as a purely mathematical device to count configurations in a model of a molecular gas. But Planck's application to the problem of blackbody radiation was subtle, and to date historians continue to disagree on its interpretation.[1–4]

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Notes on the New Big Science

Robert Crease and Catherine Westfall, in their article "The New Big Science" (Physics Today, May 2016, page 30), describe how materials science has taken over national laboratory facilities formerly occupied by high-energy particle physics. That is an interesting transition for materials science. But unfortunately, the claim that "Big Science isn't what it used to be" seems true only in a more limited sense than the title implies.

As the authors note, US particle physics is now carried out mainly abroad. But the focus on ever-larger accelerators has simply moved to the Large Hadron Collider at CERN. The LHC's community of 10 000 and annual budget of $1 billion dwarf the materials science effort at Brookhaven National Laboratory.[1]

Crease and Westfall acknowledge that their discussion omits astronomy. But the huge 30-meter-class telescopes and the 4-meter-aperture solar instrument are presently the main arena for Big Science in the US (reference 2; see also Physics Today, October 2005, page 30). The article also doesn't mention how university plasma research has been marginalized since the 1970s by increasingly large fusion machines, their growth culminating in the deeply troubled ITER project. Overall, I doubt that a more balanced analysis would support the view that Big Science has changed meaningfully.

The authors do not mention that US particle physics left the national labs precisely because the discipline was devastated by the termination of the overly ambitious Superconducting Super Collider in 1993. Hundreds left the field, once the flagship of US science, for astronomy or to work for hedge funds.[3] It is troubling that now Big Astronomy is following the same precarious path, closing even large telescopes to build a few behemoths.[4]

The authors describe well the increased complexity of materials science at the national labs. Perhaps that community can, in time, learn to manage the complexity in ways that will guide others to the benefits of Big Science while avoiding its dangers.

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▶ **Crease and Westfall reply:** The fact is that the largest projects at the US national laboratories are now devoted to materials science rather than high-energy physics. That development has been accompanied by important changes in research and the research culture at the labs, which we characterize by coining the phrase the New Big Science. ("Isn't what it used to be" was added by the editors.) We believe it is important to understand the changes. We leave it to others to explore the course of Big Science outside the US and how large astronomical projects fit into the mix; we deliberately refrained from discussing those topics in our article.

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