

than modeling only what is likely to occur.

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Explaining a few discoveries

The editorial "Discoveries and explanations" by Charles Day in the March 2017 issue of PHYSICS TODAY (page 8) discusses the work of my late colleague Vera Rubin. She showed that the rotation curves of stars in the outskirts of spiral galaxies were flat rather than Keplerian, which implied the presence of large amounts of dark matter. The history of that discovery deserves some elaboration, not to diminish Rubin's influential work but to highlight its precursors.

Rubin's first paper reaching that conclusion,¹ with coauthors W. Kent Ford Jr and Norbert Thonnard, was published in 1978. Over the preceding decade, several researchers had already found that the rotation curves of neutral hydrogen gas in spiral galaxies were flat, and they concluded that those galaxies contained at least as much dark mass in their outskirts as the mass in visible stars and gas.² In 1974 two independent groups, one in the US³ and one in Estonia,⁴ used those results, along with fragmentary evidence from various other sources, to argue that galaxies were surrounded by extended halos of dark matter containing up to 30 times the mass in visible stars. Reference 3 is particularly notable because it estimated that relative to the critical cosmological density, the density Ω of

dark and luminous matter was ~ 0.2 , remarkably close to the best current estimate⁵ of $\Omega = 0.308 \pm 0.012$.

Many of the earlier papers are cited in Rubin and coauthors' 1978 paper, which states explicitly that "[Morton] Roberts and his collaborators deserve credit for first calling attention to flat rotation curves."

Like Saul after his conversion on the road to Damascus, Rubin accepted a revolutionary idea after it was fully formulated, and she became one of its most effective advocates.

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In his March 2017 editorial, Charles Day implies sexism and possibly slights the Royal Swedish Academy of Sciences by asserting that a poorly qualified Nobel evaluation panel is a principal reason for Lise Meitner's not being awarded a Nobel Prize for her and her nephew Otto Frisch's explanation of the fission of uranium. However, it would have strengthened his case if he had provided a background or reference of earlier events that may have influenced the academy.

James Chadwick, in Germany with Hans Geiger at the beginning of World War I, was able to continue some of his studies using improvisations and materials provided by German scientists. He found that the energy spectrum of electrons emitted in beta decay was continuous with a defined maximum energy. His initial results were obtained while he was in a German prison camp during World War I. Depending on the radioactive source, some weak lines were superimposed on a continuous spec-

trum. Chadwick used two methods to measure the electron energies: the deflection of the beta rays in a magnetic field and a method that exploited the known ionization-energy thresholds of the electrons.

The explanation offered by Meitner was that the beta electrons lost energy by several mechanisms, including collisional interactions with the substrate of the beta-ray source.

However, the heating measured from the beta-decay electrons corresponded to the mean energy of Chadwick's distribution and not to the maximum electron energy. Meitner and her colleagues, possibly influenced by the defined energy peaks found in alpha decay, held fast for approximately 15 years to their explanation that the beta-ray energies were quantized. Charles Ellis and William Wooster set up a sensitive experiment to measure the total energy of the beta electrons. They inserted their radioactive sample into a thermal calorimeter that had been calibrated by collecting electrons of known energies.

Ruth Lewin Sime's biography¹ of Meitner briefly mentions the 1924 paper² by K. George Emel us (my thesis adviser) reporting that there was just over one electron per "radium E" (bismuth-210) decay. If only one electron were emitted, the decay process could not possibly have satisfied conservation of energy and momentum. Then Meitner's student Nikolaus Riehl repeated Emel us's experiment, with about the same result. Still, Meitner did not regard those results as proof of the energy spread of the primary electrons. She did become less confident of her long-held conviction of a discrete quantized electron-energy spectrum.

Later experiments confirmed the continuous energy spectrum, and eventually Meitner and others accepted the results. The long delay until Wolfgang Pauli suggested the antineutrino was at least partly because of Meitner's unusual and uncharacteristic refusal to accept the continuous electron-energy spectrum.

Meitner may well have deserved the Nobel Prize. However, the Royal Swedish Academy of Sciences may have been influenced by this long controversy.

Possibly more important was a much earlier, well-documented precedent for a correct explanation of nuclear fission by another competent female scientist, Ida

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Noddack, who earned her doctorate from the Technical University of Berlin in 1921. At the Physico-Technical Research Agency in Berlin, she worked alongside Otto Berg and Walter Noddack, her future husband. In 1925 they discovered element 75, rhenium.

In her 1934 paper “On element 93,” Noddack did not accept Enrico Fermi’s claim to have possibly produced transuranic elements.³ Noddack wrote, “It is conceivable that the nucleus breaks up into several large fragments, which would of course be isotopes of known elements but would not be neighbors of the irradiated element.”

Although the paper was generally ignored, it now serves as one of the earliest expressions of the idea of nuclear fission. There was no excuse for the paper being overlooked, since Noddack sent copies to Otto Hahn and to Fermi. The paper also was probably available to the academy, since Noddack was three times nominated for a Nobel Prize. Very much later, after he was awarded his Nobel Prize, Hahn acknowledged his mistake in not paying sufficient attention to Noddack’s paper. Ironically, Fermi is reputed to have not endorsed Noddack’s work because of the controversy over her team’s discovery of element 43, now called technetium.

Carsten Jensen’s book *Controversy and Consensus* contains a detailed account of the early beta-decay events.⁴

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Charles Day, in his editorial “Discoveries and explanations,” uses Christopher Columbus as an example of a quintessential “discoverer” and erroneously states that in May 1498 Columbus “set out . . . on his third and final voyage” (emphasis mine). Day’s story forgets what followed after that third

voyage, which ended when Columbus was arrested and shipped back to Spain in chains for committing atrocities, including enslaving the local population in defiance of Queen Isabella’s orders: Columbus returned to the Americas in 1502 on his fourth voyage.

The story of Columbus’s visits to the Americas has been mangled and abridged for centuries—most famously by the persistent and baseless conflation of his voyages with the flat-Earth myth.¹ Perhaps that tendency comes from the

discordance between using Columbus as an exemplar of discovery and acknowledging his crimes against humanity, which were widely condemned even during his lifetime.

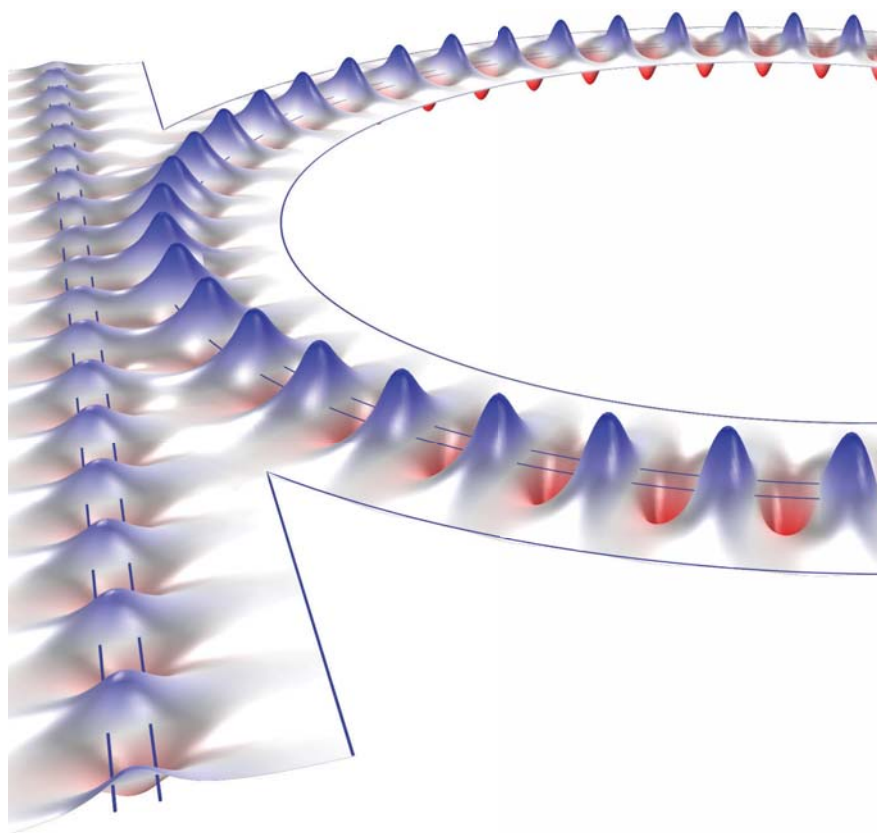
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