Tycho's Island, Where 'Big Science' Was Born

On Tycho's Island: Tycho Brahe and His Assistants, 1570–1601

John Robert Christianson
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Reviewed by Mary Lou West

John Robert Christianson contends that Tycho Brahe invented "big science" when, in the late 1500s, he developed the research complex Uraniborg on the island of Hven in Copenhagen Sound. *On Tycho's Island* convincingly supports this thesis by providing long lists of people who worked there, instruments they designed and used, their observational protocols, and their methods of data reduction. The complex was the site of many chemical, medical, map-making, printing, and waterworks activities, as well as the astronomical observations of the positions of planets and comets for which Brahe is justly famous. King Frederick II of Denmark supported the institution financially because of the international prestige it garnered and the increased educational opportunities it made available to his subjects.

Christianson shows how a summer on Hven became an expected capstone of a European college education, and students arrived in groups of 5–10, rather like an early REU (research experience for undergraduates) program. Graduates and postdocs signed contracts to work there for one to five years in return for room and board and an annual suit of clothes. If they were useful, then Brahe brokered permanent jobs for them at schools, parishes, or universities in a well-established patronage network. Most of these young men (and one woman) were aristocrats, but some were bright farm boys. Brahe's chief assistant, Christian Longomontanus, the son of peasants, probably would have succeeded him as imperial mathematician at Prague if he, rather than Johannes Kepler, had been present at Brahe's death.

The book describes the path from astronomical determinations of latitudes and triangulation measurements to the first accurate maps of many regions of northern Europe. Brahe often sent young colleagues out as couriers with letters, scientific papers, poetry, and mechanical devices as gifts to important people in the patronage network, making measurements of latitude with portable sextants wherever they went. One of the first scientific expeditions of modern times was Elias Morsing's journey in 1584 to determine the exact latitude of Copernicus's observatory, so that his data could be combined with recent measurements from Uraniborg.

Christianson describes Brahe's legacy as his empiricism, his methods of observation with errors determined, and his mathematical data analysis, including an early form of logarithms. Although he was Tycho Brahe's heir, Kepler was not interested in organizing large-scale projects. Twenty-six years after Brahe's death, he published the Rudolphine Astronomical Tables, which enabled astronomers to calculate planetary positions for any time in the past or future. Thereafter, "aristocratic big science gave way to a brilliant scattering of individualized science by middle-class scholars."

As a nonspecialist reader, I longed for a handy map of Denmark with places like Skåne, Ribe, and Stjernholm marked, and also for a large map of northern Europe, so that I could better picture the travels of Brahe's wagon entourage from Rostock to Wandsburg to Prague, after his self-exile from Denmark. Since much of the patronage system of those days depended on links to relatives, a chart of the extended Brahe-Bille-Rosenkrantz family would have been useful too, and a graphic timeline of these people's comings and goings to Hven could have been illuminating. A short discussion of Brahe's lunar and solar theories as they evolved would also have been appreciated. Christianson said his overflowing shoebox database of Brahe's coworkers prompted him to publish this compilation before he retired from Luther College in Iowa. I hope that someone else will carry on the work, as he suggests. These interesting stories cry out for a better integration.

On Tycho's Island brims with intriguing material, including 53 pages of footnotes and references that could have been presented better (unless the only intended audience is other historians). The general reader might best read the first few pages of each chapter, then skip to the last third of the book, which contains lively short biographies of the individuals who worked with Tycho or visited Hven. The 1990 book by Victor E. Thoren and Christianson, *The Lord of Uraniborg* (Cambridge U. Press), remains the best biography of Tycho himself.

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The Physics of Particle Detectors

Dan Green
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Particle detectors are essential to a broad range of high energy physics studies, both cosmic and accelerator. Detectors allow us to see such diverse objects as neutrinos from supernovas, decays of mesons containing heavy quarks, and W and Z gauge bosons. Future discoveries such as the putative Higgs boson and crucially important measurements such as charge conjugation–parity (*CP*) violation in B meson decay will be made with particle detectors. Yet the actual science of the workings of detectors is often ignored; generalized training in detector technology is frequently overlooked. Dan Green's *The Physics of Particle Detectors* makes a good effort to present in one volume all the basic ingredients necessary for an elementary understanding of the workings of most detectors used in particle physics.

This book is directed toward graduate students and other researchers in the field of experimental elementary particle physics. Green is a leader in the construction of the CMS detector for the 14-TeV proton–proton Large Hadron Collider at CERN. Detectors such as CMS are combinations of many subdetectors, each one based on a different technology and each having a unique function. Rather than focus on the direct knowledge necessary to construct a particular system, this book examines the fundamental physics behind the interactions of particles with matter and how these interactions can be exploited to reveal some property of the particles—their mass, momentum, or energy, for example.

The Physics of Particle Detectors is full of insights and serves as a useful educational tool. (For example, the fact that nuclear cross-sections scale as the 2/3 power of the atomic number is derived geometrically.) Problems are provided at the end of each chapter; this book could be the basis of a course, in a summer school, for instance. Overviews are given of entire detector systems and a clear distinction is drawn between nondestructive (or essentially nondestructive) measurements and absorption devices that destroy the particles.

The introductory material is done rather intuitively, without rigorous derivation. This approach works, because the author freely declares his tactic and refers us to more rigorous descriptions. Specific sections differ in quality. The sections on transition radiation, magnetic fields, and electromagnetic and hadronic calorimetry are excellent. In these areas the explanations are clear and examples are provided. The basic idea that transition radiation depends on having many crossings of thin media is explained nicely. The discussions of calorimetry are particularly clear. The section on Cherenkov radiation is less well done. Distinctions, in principle, between threshold and ring-imaging devices are lost, and the sources of ring-radius error are not discussed. Several large and innovative RICH (Rich Imaging Cherenkov) systems constructed in the 1990s for the DELPHI, SLD, BABAR and CLEO III experiments are not mentioned, and the reference list is incomplete. Furthermore, some important topics are not covered: scintillating fiber tracking systems and pixel detectors, for example. However, this is to be expected in such an all-encompassing work.

The Physics of Particle Detectors is a welcome companion to other works, including volumes that give more details about specific technologies or provide more rigorous derivations. Among these other works are the companion volume in the Cambridge U. Press Series, *Particle Detectors,* by Klaus Grupen, (1996); *Techniques for Nuclear and Particle Physics Experiments*, by William R. Leo (Springer-Verlag, 1994); *Introduction to Experimental Particle Physics*, by Richard Fernow (Cambridge, U. Press, 1986); *Detectors for Particle Radiation*, by Konrad Kleinknecht (Cambridge U. Press, 1998); the more specific *Particle Detection with Drift Chambers*, by Walter Blum and Luigi Rolandi (Springer-Verlag, 1994); and *Instrumentation in High Energy Physics*, by Fabio Sauli (World Scientific, 1992). In addition, proceedings of various schools and conference series are great resources.

These include the proceedings of the ICFA (International Committee on Future Accelerators) Schools on Instrumentation in Elementary Particle Physics (World Scientific, 1988, edited by C. W. Falbjan and J. E. Pilcher; World Scientific, 1992, edited by J. C. Angus et al.; AIP Press, 1998, edited by G. Herrera Corral and M. Sosa Aquino); and AIP Press, 2000, edited by Sehban Kartal). There are also the "Beauty 1993–2000" series, published in the journal *Nuclear Instruments and Methods*, the last in volume A446 (2000), and the three conferences on Cherenkov radiation published in *Nuclear Instruments and Methods in Physics Research*: (1) "Experimental Techniques of Cherenkov Light Imaging, A343 (1994), edited by Eugenio Nappa and Thomas Ypsilantis; (2) "Techniques and Results of Cherenkov Light Imaging in High Energy Physics," A371 (1966), edited by Tord Ekelöf; and (3) "Advances in Cherenkov Light Imaging Techniques and Applications," A488 (1999), edited by Amos Breskin, Rachel Chechik, and Thomas Ypsilantis.

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The Feynman Integral and Feynman's Operational Calculus

Gerald W. Johnson and
Michel L. Lapidus
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$160.00 (771 pp.).
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I have been interested in mathematical approaches to the Feynman path integral ever since I attempted in the 1950s to define functional Fourier transforms in terms of Wiener–Hermite expansions. Therefore, I was intrigued by the appearance of this monumental volume. I confess first thinking of the famous quotation by Goethe, who said, "Mathematicians are like Frenchmen: You tell them something, they translate it into their own language, and then it becomes something completely different." (This is particularly the case since both authors are mathematicians and one of them is French). I must say at the outset, however, that large parts of Gerald W. Johnson and Michel L. Lapidus's *The Feynman Integral and Feynman's Operational Calculus* are accessible to less mathematically inclined theoretical physicists, who can certainly skip some of the mathematical detail).

The idea behind the Feynman path integral goes back to a paper by P. A. M. Dirac published in 1933 in *Physikalische Zeitschrift der Sowjetunion*. It formed the core of Richard Feynman's space–time approach to quantum mechanics and quantum electrodynamics. Although the path integral was not mathematically well defined, it was widely used in quantum field theory, statistical mechanics, and string theory. Recently, path integrals have been the heuristic guide to spectacular developments in pure mathematics.

It was clear to Feynman that his "path integral" was no integral in the ordinary sense of the word, and that what he called its "summation over histories" did not involve a measure in the usual sense. Furthermore, the Lagrangian of a classical particle involves its velocity, whereas the paths over which the "integral" is extended are just continuous, not necessarily differentiable. The imaginary exponential is a highly oscillatory function, and thus most contributions cancel (except near the stationary values of the action—the classical trajectories of the particle).

In the 1920s, Norbert Wiener, extending the early work on Brownian motion by Albert Einstein and Marian Smoluchowski, introduced the notion of integration in function spaces that now goes under the name of Wiener measure, or Wiener integral. It plays a fundamental role in the theory of stochastic processes and, as distinguished from Feynman's path integral, has a rigorous mathematical underpinning. In 1947, Mark Kac realized that if one replaces the time parameter in the imaginary exponent in the Dirac–Feynman expression for the action with a pure-