

The Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe

By Frank Close

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Our best understanding of physics is predicated on something known as quantum field theory. Unfortunately, in its raw form, it doesn't make sense—its outputs are physically impossible infinite percentages when they should be something simpler, like the number 1. The kind of physics that the Higgs boson represents seeks to “renormalize” field theory, forcing equations to provide answers that match what we see in the real world.

The Infinity Puzzle is the story of a wild idea on the road to acceptance. Only Close can tell it.

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Editorial Review

Review

Ars Technica

"*The Infinity Puzzle* is eminently readable. It has no equations—only a few Feynman diagrams—and a glossary in the back so you don't get your bosons confused with your hadrons.... All of the luminaries of twentieth century particle physics are here, along with many unsung heroes whose contributions Dr. Close explains and puts into context so they can be better appreciated by a public hitherto ignorant of their work.... [T]he entire book is a very manageable introduction to quantum physics for those who are interested in, but possibly intimidated by, understanding the inner workings of the fabric of our Universe."

Science News

"Building the standard model, the flagship theory of modern particle physics, was no mean task. It took decades of painstaking work to bring the forces and elementary particles that make up the universe together in a single framework (which still doesn't include gravity). Close, a theoretical physicist, chronicles this history from an insider's perspective.... the story doesn't unfold as a simple, clearly developing line of thought. Instead, the reader witnesses scientific progress in all its real-world messiness. It's a comedy of errors at times, full of dead ends, missed opportunities and ideas that lie dormant for years, unproven or unnoticed."

The Economist

"Mr Close, an accomplished particle physicist in his own right, enjoyed unprecedented access to all the principal players, many of whom he either knows well or, like Mr Higgs, has spoken to at length. He also appears to have left no relevant academic paper, no conference proceedings, memoir or other publicly available source unturned. This painstaking attention to historical detail yields many gems.... Mr Close's magisterial work is sure to become the definitive account of the story. It offers no unambiguous advice to the Nobel committee. But the judges would be wise to give it a thorough read anyway."

CHOICE

"A detailed and compelling account of advances in particles physics over the last 60 years. Close's distinguished career as a professional physicist has enabled him to meet many of the protagonists who made these advances, giving his account the personal perspective of an insider.... Through careful use of analogies and precise prose, Close explains how the infinity puzzle was confronted and overcome repeatedly in the last few decades.... A wonderfully written book that is valuable for all readers. Highly recommended."

New Scientist

"[A] thoroughly researched and well-crafted narrative.... [Close] focuses on the triumphs and failures of the physicists behind the equations, providing a realistic view of how theoretical physics really progresses – the all-too-human endeavour fraught with personal ambitions, rivalries, alliances, errors and plain historical accident.... It's refreshing to read a popular physics book that doesn't revisit the same well-trodden ground of so many before it."

BBC Focus

"[A] masterpiece.... Close has done his homework thoroughly, interviewing just about all the protagonists that are still alive and going back to original source material for his facts, which often contradict the memories of even the most reliable of those survivors.... This book is essential reading—I never normally

give five stars, but for this I'll make an exception."

The American Scholar
"The book brims with charming anecdotes about particle physics between the 1950s and 1980s, when breakthroughs came almost too fast to be comprehended and every scientist seemed to be maneuvering (and occasionally begging) for Nobel prizes. But the book also plumbs the origins of modern physics, especially troubles with the concept of infinity."

Discovery News
"Close's book veers from the usual popular science treatment of the topic to focus on quantum field theory, described as 'our best understanding of physics'—and yet very few folks outside of physics have a clear grasp of what it is, and why it's so significant. A great read for those who've been following the Higgs story closely and are intrigued by some of the deeper questions."

Manjit Kumar, author of *Quantum*
"The nature of the problem, how it was solved, and the inevitable jostling for Nobel Prizes are major themes of Close's gripping and extensively researched narrative history of particle physics over the last sixty years.... Close has succeeded in humanising a dramatic era of physics in what is my science book of the year.... 'Hold Infinity in the palm of your hand,' William Blake wrote in the *Auguries of Innocence*. Frank Close does a fabulous job of reconstructing how physicists like Feynman and 't Hooft managed to do exactly that."

Alan Boyle, MSNBC.com's *Cosmic Log*
"In his new book, Oxford physicist Frank Close reviews decades' worth of brain-teasing theories and looks ahead to puzzles yet to be solved.... Close's tale illustrates that the course of true science doesn't always run smooth. It may well turn out that the long-sought Higgs boson is a will-o'-the-wisp, and physicists will have to go back to square one. But even that won't render *The Infinity Puzzle* out of date."

American Scientist
"[An] intriguing tale.... A treasure trove."

Chad Orzel, *Uncertain Principles*
"[A]bsolutely fascinating.... a highly readable and detailed history of what is arguably the best-tested theory in the history of science.... If you're interested in what we *know* to be true about the universe and how it works, and how we put that knowledge together, I highly recommend this book."

MAA Reviews
"Superb.... *The Infinity Puzzle* presents in light and fetching prose a (and you should pardon the pun) close-up of a wonderful set of episodes in contemporary science centered around one of the single most beautiful edifices of modern theoretical physics, quantum field theory, and leading up to the hottest example of big science to be found on the globe today."

Kirkus Reviews
"Close chronicles the search for the elusive Higgs Boson particle (the 'God Particle').... Throughout, the author chronicles the winners and losers in the annual Nobel sweepstakes, giving them recognition for their achievements and providing a lively thread for readers."

Peter Higgs, Emeritus Professor of Physics, The University of Edinburgh
"It is a pleasure to read a book on recent advances in our understanding of the structure of matter by an

author who not only understands the subject but also takes care to investigate conflicting accounts of how these advances came about."

Steve Nadis, coauthor of *The Shape of Inner Space*
"As someone who can deftly explain abstruse quantum field theory to a lay reader, Frank Close is a rarity among physicists. Rarer still, he knows how to weave a compelling tale—that of the 'infinity problem,' which has bedeviled the field of quantum electrodynamics and subsequent attempts to unify the forces of nature. The result is a great scientific whodunit, replete with a large, engaging cast of characters, behind-the-scenes maneuvering, and unexpected twists and turns. Here is proof that Close belongs among the very first rank of scientist-authors. I strongly recommend *The Infinity Puzzle*."

Peter Woit, *Not Even Wrong*
"[A] fascinating new book.... Knowing the history of a subject has always seemed to me an integral part of really understanding it, so I'd argue that anyone who wants to really understand modern particle physics should spend some time with a book like this…. [I]f like me, you're fascinated by this history and want to learn something new about it, go out and get a copy soon."

Publishers Weekly
"Close voyages through the major scientific discoveries in high energy physics that began in 1928, when Paul Dirac married quantum mechanics with Special Relativity, laying the basis for the major technical advances from which we benefit in today's digital world. Along the way we meet some major figures in the field whose breakthroughs have illuminated the deepest mysteries of physics and cosmology, resulting in an engrossing history that's also accessible for a general audience."

Dan Hooper, Fermi National Accelerator Laboratory and University of Chicago; author of *Dark Cosmos* and *Nature's Blueprint*

"The development of quantum field theory is among the very greatest achievements of humankind, on par with those of Einstein, Newton and Darwin. Frank Close introduces these difficult ideas with a rare clarity and simplicity. Anyone who wants to understand why we built the LHC and what we hope to learn from it should read this book."

Booklist
"[Close's] presentation lucidly acquaints readers with physicists' quest for the Higgs boson (theorized to cause mass) that Europe's Large Hadron Collider was built to find."

Nature
"[A] fascinating book.... [A] compelling history and sociology of modern particle theory. We discover the motivations and achievements of a rich cast of brilliant individuals, and get enough of the science to grasp what they were trying to do. Where Close really shines is in exposing the fraught process of recognition in science.... Close's history of the field is engaging and gives insight into how great theories are created."

About the Author

Frank Close is a Professor of Theoretical Physics at Oxford University and Fellow and Tutor in Physics at Exeter College, Oxford. He is the winner of the Kelvin Medal for the public understanding of physics and the author of ten books. He lives in Abingdon, England.

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Amsterdam, 1971

And now I introduce Mr. 't Hooft, who has a theory that is at least as elegant as anything we have heard before.
—Tini Veltman, "amsterdam international conference on elementary particles," 1971

Tini Veltman is a contrarian: a forthright man who has never shied away from controversy. His single-mindedness has brought him success where others either gave up or didn't even dare to try. It is the characteristic that set him on course to a Nobel Prize for Physics. Part of the reason for his triumph was the fortune to have a student whose genius was in constructing a masterpiece by using tools that Veltman had forged. Veltman and his protege, Gerard 't Hooft, are like chalk and cheese. Veltman is a big man, with a fulsome beard, often found with a cigar stuck in the corner of his mouth or waved between his fingers as he holds court. His near-perfect English resonates with Dutch vowels as he dismisses some rival's work as "baloney" or "crap." This blunt approach can mislead, obscuring a sensitive and thoughtful personality, with deeply held convictions about the way science should be conducted. His nickname, "Tini"—an abbreviation of Martinus—is ironic given his stature, in all senses of the word.

't Hooft, by contrast, slight in build, with thinning hair, dressed smartly in jacket and tie, and with a small mustache, could easily be mistaken for an English country doctor or an accountant. During discussions, I am often possessed by a sense that he already knows what he is being told and is politely waiting to hear something novel. When he speaks, there is no doubt that he is correct: His soft voice carries real force, aided by a dry sense of humor.

Forty years ago, their meeting would change the world of physics. However, today, Veltman—the teacher whose ideas enabled his star pupil to produce his magnum opus—and 't Hooft have drifted apart. In Veltman's own book about particle physics, 't Hooft's appearance is limited to a photograph and a few lines of text. He describes 't Hooft's breakthrough as "a splendid piece of work," which, enigmatically, he was very happy with "at the time." That is how it was in 1971, when Veltman "proudly introduced" his young maestro to the world.

The Infinity Puzzle

A half century or so ago, and more than two thousand years after the philosophers of ancient Greece had first conceived of atoms, these basic pieces of matter had been revealed to consist of smaller particles, of lightweight electrons remotely encircling a bulky central nucleus.

In the aftermath of Hiroshima, where the nuclear atom's explosive power had been revealed, understanding the nature of the atomic nucleus and the mysterious forces that control it was what defined the new frontier. That the nucleus of an atom has a labyrinthine structure of its own was already apparent; the surprise was that the closer that scientists looked at it, the more complicated things appeared to be. And to cap it all, strange particles—similar to those found on Earth, yet behaving in other ways—were discovered to be pouring down from the heavens, as the result of cosmic rays from outer space smashing into the atmosphere above our heads. Exotic forms of matter, whose existence had not been dreamed of by scientists in their earthbound laboratories, were changing our whole perception of nature. Any theory of the universe had to explain them.

This was a time when the pursuit of breakthroughs had become the physics world's equivalent of the Klondike gold rush. Some theoretical high-energy physicists staked their claims with half-baked theories, which they published in obscure journals. The logic seemed to be that if your idea turned out to be wrong,

few would notice and the paper would be quietly forgotten. However, if it turned out that a discovery proved your idea to have been correct, you could then refer the world back to your paper and claim priority.

Throughout this febrile period, one problem stood out, resisting all attempts at a solution. This was what I call the “Infinity Puzzle.” Three great theories—Maxwell’s theory of electromagnetism of the nineteenth century, Einstein’s theory of special relativity of 1905, and Quantum Mechanics, developed in the 1920s—individually made profound predictions that turned out to be completely accurate: for example, the description of light as electromagnetic waves with a constant speed; the conversion of mass into energy via E=mc2, where *c* is the speed of light; and the explanation of the stability of atoms, with a quantitative description of their beautiful spectra. In the 1930s the union of these theories gave birth to a complete theory of electromagnetic force and how light interacts with atoms, known as Quantum Electrodynamics, or QED. Initially, it appeared beautifully seductive, but what at first had appeared to be a Cinderella soon threatened to become an Ugly Sister. When the equations of QED were applied beyond the simplest approximations, they seemingly kept predicting that the chance of some things occurring was “infinite percent.” Why is this a problem? The answer is that infinity is transcendent, beyond measure, signifying a failure of understanding rather than a real answer.

To put this into context, the probability of chance can range from zero (that I will never win the lottery, for instance, as I never buy a ticket) to an absolute certainty at 100 percent (death and taxes). “Infinity,” by contrast, is boundless and immeasurable; it has no quantifiable meaning. In the context of the questions that the scientists were posing, the answer was nonsense, analogous to your computer giving you an error message: “computer violation” or “overflow.” When this happens it is usually a hint that you have made some catastrophic error—such as instructing the machine to divide by zero. Or it may be a sign that there is a glitch in your computer, perhaps even that the machine itself has been assembled incorrectly.

Without doubt “overflow”—or in our example, infinity—is telling you that something is wrong; the problem is: What to do about it?

Nor was this a nonsense confined to some arcane piece of atomic science, for this enigma touched upon our ability to understand the principles underlying some of the most basic and far-reaching phenomena. Plants grow as their atoms absorb energy from light, for instance; radio waves result when electric charges are disturbed by electric or magnetic forces; and much of modern electronic technology involves the interactions between electromagnetic radiation and electrons. Each of these— whole industries and indeed many forms of life itself—depends on a simple underlying mechanism: an electron absorbing or emitting a photon, which is the basic particle of light. Yet QED seemed unable to agree with even this most rudimentary of processes. If, as QED seemingly implied, the chance of a photon being absorbed by an atom was infinite, then photosynthesis and indeed many chemical reactions would happen instantaneously. Life would have burned itself out long ago, if indeed it had ever begun.

For physicists, *infinity* is a code word for disaster, the proof that you are trying to apply a theory beyond its realm of applicability. In the case of QED, if you can’t calculate something as basic as a photon being absorbed by an electron, you haven’t got a theory—it’s as fundamental as that.

One particular example of this catastrophe is the magnitude of an electron’s magnetism, which experiments could measure relative to some standard scale. By using the standard theory, that is, QED, physicists expected to be able to compute this number. All that is required is to solve the algebraic equation describing an electron absorbing a single photon.

This is standard fare in undergraduate physics, and I can well recall the joy I felt when, back in 1967, I first

carried out the calculation myself. I thought that at last I had qualified as a theorist. Unfortunately, I then learned that this was just the first of a whole series of calculations that would be needed in order to arrive at the true answer; furthermore, my tutor had glossed over the fact that if I were somehow able to do this momentous task, and then to add up the total, the answer would turn out to be infinity. Unknown to me at that time, a few hundred miles away, in Holland, I had a contemporary named Gerard ’t Hooft, who was also being exposed to the mysteries of infinity and within five years would gain scientific immortality by solving them.

Users Review

From reader reviews:

Jeffrey Brill:

The book The Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe will bring that you the new experience of reading any book. The author style to spell out the idea is very unique. In the event you try to find new book you just read, this book very suited to you. The book The Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe is much recommended to you you just read. You can also get the e-book from your official web site, so you can quicker to read the book.

Nick Zapata:

Precisely why? Because this The Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe is an unordinary book that the inside of the book waiting for you to snap it but latter it will distress you with the secret that inside. Reading this book beside it was fantastic author who have write the book in such awesome way makes the content inside of easier to understand, entertaining means but still convey the meaning entirely. So , it is good for you for not hesitating having this anymore or you going to regret it. This excellent book will give you a lot of gains than the other book possess such as help improving your proficiency and your critical thinking way. So , still want to hold off having that book? If I have been you I will go to the guide store hurriedly.

Shirley Demers:

Your reading 6th sense will not betray you, why because this The Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe e-book written by well-known writer who really knows well how to make book which can be understand by anyone who have read the book. Written within good manner for you, leaking every ideas and composing skill only for eliminate your own personal hunger then you still question The Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe as good book not merely by the cover but also through the content. This is one guide that can break don't ascertain book by its include, so do you still needing yet another sixth sense to pick this specific!? Oh come on your reading through sixth sense already told you so why you have to listening to an additional sixth sense.

Scott Seward:

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