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Does the many-worlds interpretation hold the key to spacetime? FREE

Something Deeply Hidden: Quantum Worlds and the Emergence of Spacetime. , Sean Carroll, Dutton, 2019, $29.00

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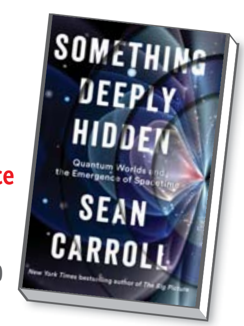
Does the many-worlds interpretation hold the key to spacetime?

I think I can safely say that nobody is as tired of a certain Richard Feynman quote about quantum mechanics as I am. We use it to say, "Look, this really smart person said that the theory cannot be understood, so we won't even try." The prologue of Sean Carroll's new book, *Something Deeply Hidden: Quantum Worlds and the Emergence of Spacetime*, is a polemic against that attitude, and I am thoroughly on board. Quotes like "Physicists tend to treat quantum mechanics like a mindless robot they rely on to perform certain tasks, not as a beloved friend" indicate that it is going to be an enjoyable read. To be clear, I disagree with almost every other opinion that Carroll states in the book, but the point of view he offers is one worth considering.

Carroll, a theoretical physicist at Caltech, sets himself the task of explaining the problems with quantum theory and how solving them may lead to progress in physics. He is an advocate of Hugh Everett's interpretation of quantum mechanics, the many-worlds theory. If you want to know why some people take that approach seriously and what you can do with it, then Carroll's latest is one of the best popular books on the market.

Something Deeply Hidden
Quantum Worlds and the Emergence of Spacetime
Sean Carroll
Dutton, 2019. $29.00



The first part of *Something Deeply Hidden* starts with a description of Everett's many-worlds view: There is only unitary evolution of a wavefunction of the universe, in terms of which everything else can be explained. It gives a concise treatment of topics such as wave–particle duality, quantum interference, Schrödinger's cat, and Einstein-Podolsky-Rosen (EPR) and Bell experiments, and it emphasizes the Everettian view on those concepts.

My only complaint about the section is its light treatment of Bell's theorem. The EPR paradox is easily resolved by imagining that quantum systems really do have definite values for each observable. Bell's theorem is needed to interpret why that solution would be problematic, but Carroll does not offer any explanation of how Bell's theorem works. Given that one of the major selling points of Everett's many-worlds interpretation is its ability to get around the limits of Bell's theorem, I would have liked to see a more detailed treatment.

The second part of the book is its real meat. Here Carroll explains how multiple worlds emerge from Everett's view, how to think about probability, and what it would be like to live in an Everettian universe. Carroll does a good job of defending Everett against common criticisms, such as that a plurality of unobserved worlds violates Occam's razor, and of explaining the role of decoherence in the emergence of worlds.

Carroll's attitude to the locality of world splitting, however, is a bit blasé for my liking. The issue is whether, when enough decoherence occurs, we should say that the entire universe splits or just the part of the universe described by the parts of the wavefunction that are entangled with the degrees of freedom causing the decoherence. To my mind, if we are to save a semblance of locality, it must be the latter. Carroll, on the other hand, says that since the concept of worlds is emergent, we should not be too bothered that there is more than one way of defining the worlds.

Physicists are used to the idea of an inherent ambiguity in defining emergent concepts—at least when that ambiguity makes no difference to the physics. But when I make a quantum measurement here on Earth, there are either immediately more moons than before or the same number. That seems like a real physical difference of macroscopic significance. More to the point, it seems like it should matter for the issue of whether Everett's many worlds really resolves the tension of Bell's theorem.

The middle section ends with a chapter on alternative interpretations, such as de Broglie–Bohm theory, spontaneous collapse theories, and quantum Bayesianism. Although Carroll charitably says he is glad others are studying those approaches, it comes off as disingenuous because he gives all of those theories bad reviews. For example, he makes a big deal of the alleged difficulties coming up with a Bohmian version of quantum field theory, but he later argues that QFT should emerge from a more fundamental discrete theory, whereas stochastic Bohm-like models for such discrete theories are known. Not that I want to advocate Bohmian theories myself, but the alternatives to Everett are not as hopeless as Carroll makes them out to be.

In the third part of the book, Carroll describes recent work by himself and others that aims to derive spacetime as emergent from quantum theory. If we look at the vacuum state of a QFT, it tends to have entanglement correlations between regions of space that decrease with the distance between those regions. The idea is to invert that relation and define space in terms of the entanglement entropy between systems in a substrate of finite-dimensional quantum systems. More ambitiously, Carroll envisages defining the areas of surfaces in spacetime in terms of entanglement and using those areas to construct a metric. That is one version of the "it from qubit" approach, which has become popular in recent years.

Noticing that two quantities are always the same and then trying to construct a theory in which they are identical has been a route to progress in the past. The fact that inertial and gravitational masses are always the same is just a coincidence in Newtonian mechanics, but their necessary identities played a part in constructing general relativity.

Correlation, however, does not always imply identity. Often, a numerical correlation between two quantities is explained by the laws of a theory rather than by a literal identity of concepts. In the case of entanglement and metric, it seems that we have a perfectly good explanation in terms of laws: The locality of the Hamiltonians of QFT, combined with the fact that the initial state is close to the vacuum state, means that entanglement will drop off with distance. If a credible quantum theory of gravity grew out of that approach, I would change my tune, but I do not see strong evidence of that.

Although I am skeptical of many of the ideas described in this book, I still think it is an excellent one. A great deal of uncertainty about the foundations of quantum theory remain—more than most physicists are willing to admit—so naturally we all disagree. This is a masterful popular account of one approach, but for true balance, you are going to have to read a lot of other books alongside it.

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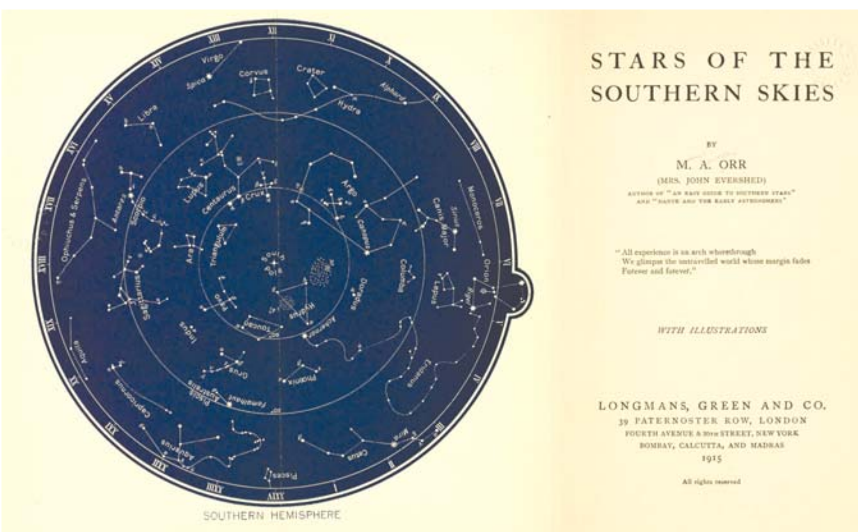

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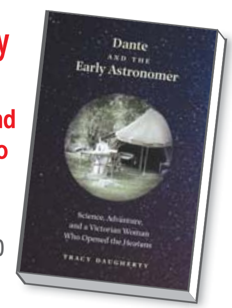
Dante and the Early Astronomer

Science, Adventure, and a Victorian Woman Who Opened the Heavens

Tracy Daugherty
Yale U. Press, 2019. $26.00



Astronomer's biography skimps on the science

Although the lives of select female astronomers, such as Caroline Herschel, have been well documented, books about women who conducted astronomical studies before the 20th century are generally few and far between. In *The Hidden Giants* (2006), Sethanne Howard reported on the lives and contributions of women scientists, including astronomers, throughout 4000 years of history. More recently, Dava Sobel told the story of Harvard computers in *The Glass Universe: How the Ladies of the Harvard Observatory Took the Measure of the Stars* (2016).

When I first heard about Tracy Daugherty's new book, *Dante and the Early Astronomer: Science, Adventure, and a Victorian Woman Who Opened the Heavens*, what most piqued my interest was the subtitle. I was expecting to read about the scientific contributions of yet another female astronomer whose story has been hidden or relegated to footnotes. I also expected to learn more about Dante and how Mary Acworth Evershed (née Orr), the Victorian woman in the title, interpreted his astronomy as written in his poetry.

The title, however, is misleading.