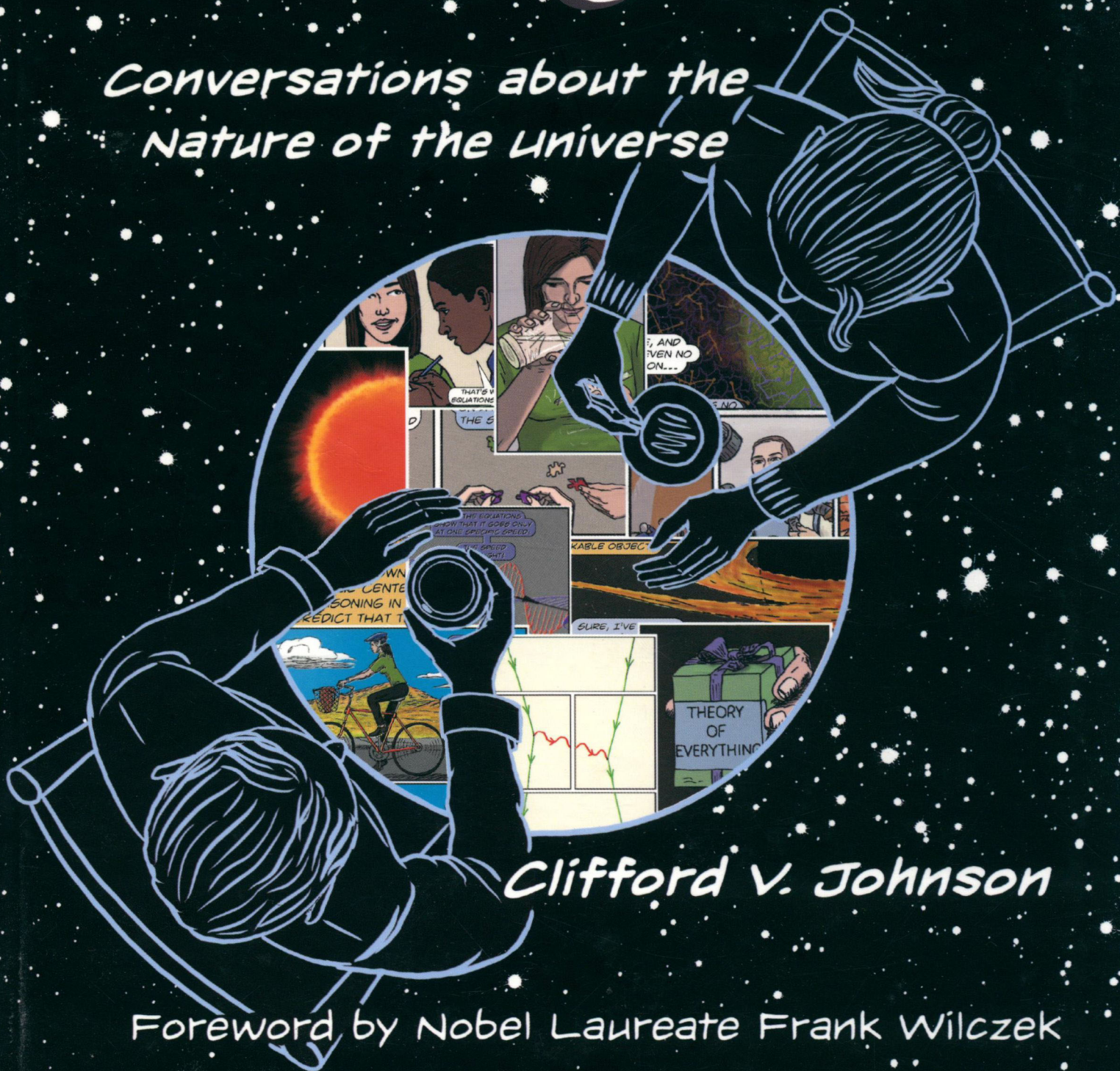


The Dialogues

*Conversations about the
Nature of the Universe*



Clifford V. Johnson

Foreword by Nobel Laureate Frank Wilczek

science/graphic novels

The Dialogues

Conversations about the Nature of the Universe

Clifford V. Johnson

foreword by Frank Wilczek, 2004 Nobel Laureate in Physics

Physicist Clifford Johnson thinks that we should have more conversations about science. Science should be on our daily conversation menu, along with topics like politics, books, sports, or the latest prestige cable drama. Conversations about science, he tells us, shouldn't be left to the experts. In *The Dialogues*, Johnson invites us to eavesdrop on a series of nine conversations, in graphic-novel form – written and drawn by Johnson – about “the nature of the universe.” The conversations take place all over the world, in museums, on trains, in restaurants, in what may or may not be Freud's favorite coffeehouse. The conversationalists are men, women, children, experts, and amateur science buffs. The topics of their conversations range from the science of cooking to the multiverse and string theory. The graphic form is especially suited for physics; one drawing can show what it would take many words to explain.

In the first conversation, a couple meets at a costume party; they speculate about a scientist with superhero powers who doesn't use them to fight crime but to do more science, and they discuss what it means to have a “beautiful equation” in science. Their conversation spills into another chapter (“Hold on, you haven't told me about light yet”), and in a third chapter they exchange phone numbers. Another couple meets on a train and discusses immortality, time, black holes, and religion. A brother and sister experiment with a grain of rice. Two women sit in a sunny courtyard and discuss the multiverse, quantum gravity, and the anthropic principle. Having read these conversations, we are ready to start our own.

Clifford V. Johnson, Professor of Physics at the University of Southern California, gives many public lectures about his research and appears often in television documentaries as an expert. He has been science advisor for several movies and television series, including Marvel's *Thor: Ragnarok* and the National Geographic Channel's *Genius*.

“This is a fantastic book – entertaining, informative, enjoyable, and thought-provoking.”

– A. Zee, Kavli Institute for Theoretical Physics, University of California, Santa Barbara; author of *Fearful Symmetry* and *Quantum Field Theory in a Nutshell*

“Two superheroes walk into a natural history museum – what happens after that will have you thinking and talking for a long time to come. Clifford V. Johnson displays a solid grasp of the craft of comics, demonstrating how this medium can be used to represent different understandings of the relationship between time and space, questions central to his native field of physics. He takes advantage of the observational qualities of contemporary graphic novels to explore the place of scientific thinking in our everyday lives.”

– Henry Jenkins, Media Scholar, University of Southern California, author of *Convergence Culture: Where Old and New Media Collide*

“*The Dialogues* is everything I would have loved as a teen physics nerd, and exactly what I want the public – and my fellow scientists – reading now that I'm a professional physics nerd. *The Dialogues* successfully upends tired traditions in science writing, which all too often rely on outdated tropes about what science is, what scientists look like, and what we can trust the public to understand.”

– Chanda Prescod-Weinstein, theoretical physicist, activist, and writer, recipient of the 2017 LGBT+physicists Acknowledgement of Excellence Award

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The Dialogues

*To my mother, who always gave me
space to explore my full potential.*

To my son, an explorer.

Foreword

Frank Wilczek is the Herman Feshbach Professor at the Massachusetts Institute of Technology, Chief Scientist at the Wilczek Quantum Center, Shanghai Jiao Tong University, Distinguished Origins Professor, Arizona State University, and Professor of Physics at Stockholm University. He shared the 2004 Nobel Prize in Physics with David J. Gross and H. David Politzer for the discovery of asymptotic freedom in the theory of the strong nuclear interaction. He has written many books and essays, including most recently *A Beautiful Question: Finding Nature's Deep Design* (New York: Penguin Press, 2015).

* * *

I.

Dialogues were Plato's chosen vehicle, through which he framed philosophical debates that continue to this day. David Hume took up the form in his brilliant *Dialogues Concerning Natural Religion*. Hume's work is a classic in the philosophy of science, as well as the philosophy of religion, and its discussion of cosmology, in particular, remains fresh and relevant today.

Galileo, a great admirer of Plato, used dialogue form in two of his masterworks. In *Dialogue Concerning the Two Chief World Systems*, two natural philosophers—Simplicio, a traditional Aristotilean, and Salviati, a Copernican—vie for the allegiance of Sagredo, an intelligent layman. The character of Sagredo is based on a real person, Galileo's friend Giovanni Francesco Sagredo. The scientific debate between Aristotilean physics (with its Earth-centered, Ptolemaic astronomy) and Galilean physics, now called "classical" (with its Sun-centered, Copernican astronomy) is now long settled. The *Dialogue's* discussion of particular points is dated and, in its extended discussion of the tides, badly misguided. Yet Galileo's *Dialogue* remains alive, and a joy to read, because it brings us in touch with sympathetic human characters, and with a wonderfully attractive interaction among them, wherein they exchange deeply held ideas—and expose them to questioning.

Galileo's *Discourse on Two New Sciences* is a more purely scientific work, in which he presented pioneering ideas in what we'd now call strength of materials and elementary dynamics. The science is brilliant, but of course long superseded. Yet the *Discourse* remains as a beautiful, touching work of literature, again because of the attractive culture it shows us, here featuring the interplay of fundamental science and engineering practice or, more broadly, theory and experiment. In this book Galileo's protagonists, although still named Simplicio, Sagredo, and Salviati, are actually all Galileo himself, at different stages in his intellectual development. Through their debate, he shows us how his ideas evolved.

II.

"Show, don't tell" is advice often given to aspiring playwrights and novelists. When done well, it leads to work that engages us like life itself. Plato, Hume, and Galileo followed that advice, to great effect. For modern scientists who aim to bring their work to the public using printed media it is challenging advice, since their material is, generally speaking, far removed from everyday life.

Clifford Johnson—a practicing scientist, working at the frontiers of physics and cosmology—has, in the book before you, risen to the challenge. He's brought in two very creative innovations.

First, and most strikingly, he's taken "dialogue" to a new level, augmenting text with graphics that depict the protagonists and their surroundings. Graphic novels have become very popular in recent years. Here we have graphic dialogues.

Graphic dialogues add important new dimensions to the dialogue form. They restore some of the richness of face-to-face human communication. Reactions are "shown, not told." The social and cultural context of the conversations is, necessarily, explicit. Facial expressions and body language are in play. Johnson places his interlocutors in interesting, realistic, physical settings. His urban "landscapes" are drawn with a skillful, loving hand.

It is all too easy to forget, in the later dry retelling, that new science is usually the product of attractive young people, who enjoy one another's company. That hidden aspect of scientific life is front and center in Johnson's graphic dialogues.

Second, he's off-loaded heavy scientific details into the brief notes that follow each dialogue. The notes provide, for those who'd like to enter the subjects more deeply, informed pointers to readily accessible sources of additional information.

The dialogues themselves are conversational. They contain, as dialogues worthy of the name should, real give-and-take about issues where the last word has not yet been spoken, and different opinions are possible.

Can there be a theory of everything? Does the concept of a multiverse make sense—and is it useful, or true? What is the value of wildly exploratory research, driven by curiosity and aesthetics rather than tangible goals?

Let's talk about it ...

Frank Wilczek
Cambridge, Massachusetts
March 2017

Preface

An Invitation

All around you, people engage with each other in conversations about a variety of topics, reflecting the diversity of interests and concerns that they have about the world around them. You've probably overheard snippets of such conversations, and although you don't necessarily appreciate every aspect of what was said (perhaps because of lack of context or knowledge of the subject), you'll probably agree that it can be fascinating while it lasts! Sometimes, those conversations are about science. They should be, since science is part of our world and our culture, and it has a huge impact on our lives. So it ought to be on the menu right alongside art, music, politics, sports, shopping, celebrities, and all those other things we talk about. Science is also a great source of beauty and wonder. There need be no more reasons beyond that to talk about a topic!

Despite all that, everyday conversation about science seems to be hidden from most of our art, our literature, and other forms of entertainment. It is even largely absent from most presentations of science. This is odd, since such conversations are essential to everyone involved: To unpack the meaning or relevance of some aspect of science, or to simply become more familiar or comfortable with a topic, it helps to talk about it with someone. When scientists are trying to understand each other's work, or uncover some new truth about how nature works, they have conversations. When they try to communicate science ideas or knowledge to the public, it's often best done in the form of a conversation.

This book is therefore an invitation. On the one hand, it's an invitation to eavesdrop on some conversations about science. Like all dialogues, they're rambling, incomplete, and sometimes not fully informed. However, they may be interesting, and they may encourage you to delve a little deeper and find out more about something you got from an exchange. On the other hand, this book is an invitation to join in! Conversation about science shouldn't be left to the experts or to science enthusiasts—it's for everyone. There's no grade given for getting things wrong, for asking questions, for hazarding a guess, or for having an opinion. So while out there in the world, remember these conversations, know that they are happening all around you, and initiate and participate in some of your own. Maybe someone will eavesdrop, start his or her own conversation, and keep the chain of engagement alive.

About This Book

Let me point out a few things about this book, since it is somewhat unusual. During or after eavesdropping on a conversation, consider consulting the notes that are at the end of each one. They're entirely optional, but they sometimes contain comments about things that were said, and they often supply sources for further reading. Remember also that vast amounts of information are available online to which you can quickly connect by putting a snippet of what was said into a search engine. In doing so, you should be cautious of your sources. I've given a few online sources, but I've focused on books. You should not consider the books listed to be what I regard as the definitive best (or most current) treatments. They are just a mixture of some of my favorites with others that caught my eye, or that seemed suitable to include to help form a collection of entry points into a topic. Read lots of sources, and get several points of view: Remember that science is a human endeavor, and so a book by one scientist on a certain topic might not resonate with you as much as one by another scientist on the very same topic. This is no different from preferring how one poet evokes a summer's day to how another does.

You'll notice that this is a graphic book, or graphic novel, or comic, or whatever the right term is. (There's no universal agreement on the terminology.) The more accurate (but less dexterous) usage is to say that this is a collection of "sequential art," meaning that it is a bunch of images that, taken together (and read with adherence to some agreed upon ordering convention) form a narrative, just like a sentence, or collection of sentences, does. But sequential art—the graphic form—can do so much more than just sentences made of words! In fact, it is particularly well suited to discussing science, especially physics, which is what most of these dialogues are about. This goes beyond the obvious fact that I can simply show shapes and objects that I'd typically have to describe in words in a traditional science book. It also goes beyond the fact that you might be drawn more readily into the conversation by being able to see the interlocutors and their surroundings. Remember that physics has space and time embedded into nearly every aspect of it. In fact, current research into the nature of space and time focuses a lot on how they may arise as a result of the relationships between things. Space and time and the relationships between things are at the heart of how comics work: Images (sometimes contained in panels, but not necessarily) arranged in sequence encourage the reader to infer a narrative that involves the sense of time passing, of movement, and so forth. In this sense, fundamentally, comics are physics! Put this way, upon reflection it is stunning that this graphic form has not been used more to talk about physics, and to communicate what's going on in the fascinating world of physics research. I hope that this book will help change that. I don't do it nearly as much as I could have, but do keep an eye out for places in the book where I tie the physics being discussed to the layout of the images on the page. In the notes I could not resist pointing out some (perhaps) particularly notable cases.

Finally, you'll also notice that there are equations in this book. In popular-level presentations of science ideas, there's a tradition of hiding from the reader the two most powerful tools we use in research: the cartoons and diagrams that we scribble, and the equations that we write. So much of the reasoning we do in physics is visual, and most ideas start that way. Those tools encode so very much in a visual language, and yet authors are encouraged by their editors to replace them with words, to effectively infantilize readers and protect them from the dreaded mathematics. It is no wonder that some topics remain mysterious, obscure, or confusing! It also ends up perpetuating the very fear and unfamiliarity with equations that some people have. To leave out (or minimize the quantity of) equations and diagrams in a book about physics is like writing a book about music and being afraid to talk about or show any musical instruments. You can do it, sure, but you're leaving out so very much of what physics is really like, hiding what makes it attractive to most of its practitioners. So yes, cast your eye over the equations, and don't worry if you don't fully understand them. Appreciate what you can. Having them on the page will get you more comfortable with them, and that familiarity may mean you'll look a second time, and a third, and so on ... and maybe you'll appreciate their meaning a bit more every time.

Acknowledgments

I'm not the first to note how overly specialized we all are. Sometimes it is out of necessity, but all too often it is because we find comfort in apparently getting the measure of someone by being able to classify them, so we all join in the classification game and end up building walls. The apparent wide gulf between my "day job" as a professor of physics and the other things I like to dabble in (aspects of the visual arts, and the humanities) that resulted in this book has meant that most friends and colleagues don't know or haven't really understood what I've been working on, or why. In some cases it has been because it was hard for me to know where to begin explaining, and so I busied myself with getting on with it, hastening the day when I could just point to the end product. So I'd like to express considerable

gratitude to everyone who (even if they did not quite understand) was either supportive, or encouraging, or who simply trusted me enough to allow me the space (and time) to work on this (more than seventeen-year-old!) idea and bring it to fruition.

I'm privileged to work at an institution (the University of Southern California) that has many staff and faculty who help keep alive the spirit of genuine cross-disciplinary exploration, and I thank them for that. Notable individuals with words of support and interest include Aimee Bender, Leo Braudy, K. C. Cole, Allison Engel, Karin Huebner, and M. G. Lord. I thank the Fellows and Friends of the Los Angeles Institute for the Humanities at USC for keeping alive the wonderful environment that makes it easy to keep sight of projects like this, and USC's Sidney Harman Academy for Polymathic Study (and especially the late Kevin Starr who helped build and guide it) for providing me with opportunities to inspire a new generation to be explorers. Both institutions let me present the book as a work in progress. I thank Amy Rowat for helpful advice on extra sources to include about food science, and Tameem Albash for patiently listening to me babble about comics. Particular thanks to Nancy Keystone for being an enthusiastic supporter from the moment she heard what I was doing. It is a delight to thank Jessie and Robin French for occasionally allowing me to set up camp in a corner of their home while working on the book. Special thanks go to Tim Morris, my old PhD advisor from almost thirty years ago. I remembered a story that he told about going to the fair with his father, and his interpretation of what happened. He gave me permission to borrow it, and the story told within the last conversation in the book is loosely based on his tale. Thanks to the Aspen Center for Physics (especially Jane Kelly) for being an excellent retreat at which to think about unusual projects. I've completed this book during a sabbatical year, and the Simons Foundation made a full year possible by awarding me a fellowship, for which I am grateful.

It was a challenge to explore the publishing world to try to find a home for this oddball project. I must thank Stephon Alexander and Cecil Castellucci for trying to help by making introductions, even though those avenues did not yield results. I've since learned that such selfless introductions to agents and editors are more rare than I'd have guessed, and so they should be acknowledged. Alice Owen was the first commissioning editor who really listened and "got it" when I found her and explained what I was trying to do, and this book may not have made it to print without her enthusiastically championing it while at IC Press, so a big thank you goes to her. I thank Jerney Matthews for the initiative and enthusiasm that resulted in this book finding a home at the MIT Press, and all the staff at the MIT Press for their warmth and professionalism as we worked on the last stages of this book.

Although I don't see them as often as I'd like, my mother, Delia, and my siblings, Robert and Carol, are with me in every project I undertake and I'm thankful. They, along with my (now departed) father Reginald, have all helped shape who I am. This includes, I believe, having been understanding and supportive of my exploratory nature all my life. I must also thank Robert for (probably) being responsible for me being exposed to comics, sharing them, and helping me track them down back when that was so hard to do, almost four decades ago on that tiny island that we all miss so much.

Most importantly, there's my wife and best friend, Amelia French. My gratitude to her cannot be overstated. It is a cliché to say that without her this project would not have come to fruition, but it is true. I thank her for being the most wonderful partner one could wish for, bringing love, humor, ideas, and the unquestioning and generous support and flexibility that allowed us to negotiate a mutually workable schedule that (I hope) ultimately served each of our respective endeavors well, as well as strengthening the wonderful family we've made. The book is infinitely richer as a result of us having met.

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