want to weaken the requirement that theories have to be tested. To my mind that's a step backward by a thousand years."

In my view, the slow pace of new discoveries in fundamental physics is to a large extent the natural outcome of our earlier, spectacular success. It's been hard to make improvements. Patience may be required. In fact, we've already learned that it will be. The good news is that there's much more to physics, and to life, than digging deeper foundations.

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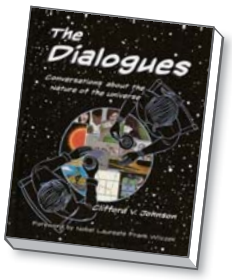
A graphic textbook imagines conversations about physics

A common misperception about comics is that the medium is childish and best left to newspaper strips or depictions of superheroes. That view fails to acknowledge how the powerful combination of text and visual depictions in comics can draw readers in and keep them engaged with a profound or complex story. The recent rapid expansion of comics into STEM (science, technology, engineering, and mathematics) teaching and storytelling has demonstrated the medium's potential. Apostolos Doxiadis and Christos Papadimitriou's *Logicomix* (2009) was a fascinating dive into the life and work of philosopher and mathematician Bertrand Russell; the Science Comics series from Macmillan has produced volumes dense with facts but endearing to read; and artists like Maki Naro and Rosemary Mosco have blended science and comics to make complicated concepts more accessible to all readers.

The Dialogues: Conversations about the Nature of the Universe by University of Southern California physicist Clifford V. Johnson attempts to use the same combination of narrative and art to open up physics. The book—"graphic textbook" is the term that feels most appropriate—depicts one-on-one conversations involving a series of characters. Johnson's conversationalists discuss concepts running the gamut from Maxwell's equations to infinity, hypothesis, and experimentation.

The conversations in *The Dialogues* mostly take place between a scientist and a person on the street. The locations vary: a museum, a coffee shop, and a train, to name a few. The scientist responds to questions or skepticism and explains complicated theories. Often the conversations end with some questions left unanswered, perhaps an attempt to pique readers' interest and encourage them to undertake further study and consideration. If a book like *The Dialogues* had no art, the conversations could seem one-sided, giving the effect of a narrator rather straightforwardly addressing the reader. The comics format, however, allows Johnson to interweave into his text questions that the reader might ask; in a sense he integrates the readers themselves into the dialogues.

The Dialogues
Conversations about the Nature of the Universe
Clifford V. Johnson
MIT Press, 2017.
$29.95



The characters are diverse in age and understanding, which can lead to abrupt shifts in tone from chapter to chapter. Moving from a young girl analyzing how rice expands while cooking to a discussion of relativity and spacetime with an adult fan of science does create an interesting sense of narrative progression. The varying levels of scientific discussion, however, make it unclear who the book is intended for.

The greatest problem with graphic works is that the art must effectively support the story. The art must be engaging in its own way, as bad art can be just as detrimental to the novel or textbook as a

bad story. The possibilities for comic art are nearly limitless; visuals can be interwoven with text and do not need to be realistically drawn. At times Johnson uses the medium to the fullest; for example, one page likens the development of theoretical physics to the assembling of a jigsaw puzzle, with comic panels and backgrounds broken into puzzle pieces. Panels breaking apart into small bits are also effective in representing quantum building blocks and the distortions of space and time near black holes.

For the most part, although the technical approach is clear and competent, the art itself is stiff and lacks emotion. Some panels are repeatedly copied to the point of distraction. The person-on-the-street characters may help make the science more engaging, but the depictions of two people talking with each other for pages on end is at times dull.

Readers of *The Dialogues* will likely appreciate Johnson's unique approach to starting a conversation about physics with a broader audience, and they'll admire his passion for the subject matter. But they will also probably wish that more of that passion came through in the art.

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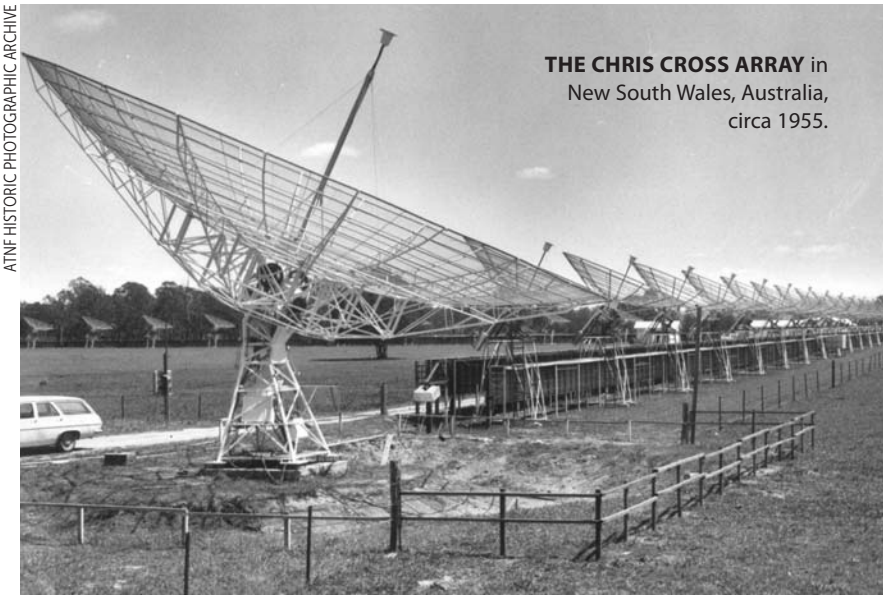


ATNF HISTORIC PHOTOGRAPHIC ARCHIVE

THE CHRIS CROSS ARRAY in New South Wales, Australia, circa 1955.

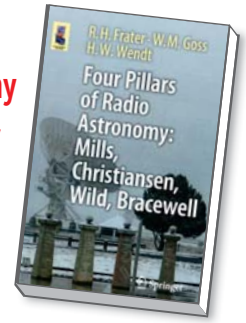
The golden age of Australian radio astronomy

In 1933 Karl Jansky announced that the mysterious source of interference in the AT&T transatlantic radio links at 20 MHz was radiation emanating from the center of our galaxy. And thus radio astronomy was born. Until the end of World War II, the subject was developed by a sole individual, Grote Reber, who built a parabolic antenna in his backyard, mapped the distribution of radio radiation along the galactic plane, and identified a number of distinct sources.

Building on the wealth of radar development during World War II, radio astronomy transitioned from small science to big science in the 1950s and is still undergoing enormous growth. The latest big radio telescope array is the Atacama Large Millimeter/Submillimeter Array (ALMA) in Chile, which cost about $1.5 billion. A comparable instrument for longer wavelengths is the Square Kilometer Array (SKA), currently under development.

The development of radio astronomy is a fascinating story that contains many lessons about how scientific enterprises grow and flourish. A welcome new book, *Four Pillars of Radio Astronomy: Mills, Christiansen, Wild, Bracewell*, by R. H. Frater, W. M. Goss, and H. W. Wendt, provides a fascinating window on the remarkable development of Australian radio astronomy in the decade following World War II. As the title suggests, the book focuses on the work of four scientists: Bernie Mills, Chris Christiansen, Paul Wild, and Ron Bracewell. That remarkable group worked at the Radio Physics Laboratory of Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Four Pillars of Radio Astronomy
Mills, Christiansen, Wild, Bracewell
R. H. Frater, W. M. Goss, and H. W. Wendt
Springer, 2017. $37.99



Mills invented the eponymous Mills's Cross, an array that produced a pencil-beam pattern. From the data it provided he derived early source-count distributions, work that had cosmological implications and led him into a bitter rivalry with a competing group in England under Martin Ryle. Mills's measurement of the position of the radio galaxy Cygnus A led to the first identification of an extragalactic radio source. Christiansen developed a different type of array consisting of two orthogonal interferometric grating arrays that produced fan beams. With it he made the first two-dimensional radio image based on Fourier synthesis of the Sun.

Wild made a clever circular array to image solar emission on short time scales and developed the first classification system for solar radio bursts. Bracewell brought the principles of Fourier transforms to bear on the analysis of data and the problem of restoring and reconstructing images; his work underlies all modern radio interferometry and contributed to the development of medical imaging.