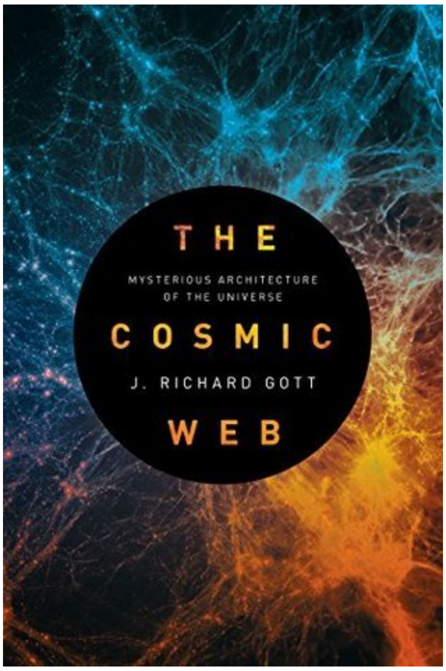

The Cosmic Web: Mysterious Architecture of the Universe

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J. Richard Gott was among the first cosmologists to propose that the structure of our universe is like a sponge made up of clusters of galaxies intricately connected by filaments of galaxies--a magnificent structure now called the "cosmic web" and mapped extensively by teams of astronomers. Here is his gripping insider's account of how a generation of undaunted theorists and observers solved the mystery of the architecture of our cosmos.
"The Cosmic Web" begins with modern pioneers of extragalactic astronomy, such as Edwin Hubble and Fritz Zwicky. It goes on to describe how, during the Cold War, the American school of cosmology favored a model of the universe where galaxies resided in isolated clusters, whereas the Soviet school favored a honeycomb pattern of galaxies punctuated by giant, isolated voids. Gott tells the stories of how his own path to a solution began with a high-school science project when he was eighteen, and how he and astronomer Mario Juri? measured the Sloan Great Wall of Galaxies, a filament of galaxies that, at 1.37 billion light-years in length, is one of the largest structures in the universe.
Drawing on Gott's own experiences working at the frontiers of science with many of today's leading cosmologists, "The Cosmic Web" shows how ambitious telescope surveys such as the Sloan Digital Sky Survey are transforming our understanding of the cosmos, and how the cosmic web holds vital clues to the origins of the universe and the next trillion years that lie ahead.

The Cosmic Web: Mysterious Architecture of the Universe Details

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From Reader Review The Cosmic Web: Mysterious Architecture of the Universe for online ebook

Brie says

I've read quite a few nonfiction astronomy books over the past several years, and this one is by far the toughest read.

While most books try to bring the concepts down a bit for a more general audience to understand, this book doesn't really do that. It's quite complicated and there are many equations and theories discussed within. Some discussions gave me a better understanding of the topic than I had before (inflation), but there were quite a few I just could not get my head around, no matter how closely I read through it.

Definitely interesting, but be ready to really pay attention and feel like you are taking a class on the topic.

Autumn Kotsiuba says

For the record, the only reason I could follow along with this AT ALL is because I recently read a book on dark matter, and I've been studying basic astronomy on my own. This may be "introductory," strictly speaking, but definitely not recommended for anyone without a grounded understanding of dark matter, physics, etc.

Gott basically takes the reader through what we've thought the universe is like throughout history. "We're at the center. The sun's at the center. We're alone. The universe is finite," and so on. The latter portion of the book explains the current theory. Though the most popular analogies have been meatball vs. swiss, he advocates for a 3D model of the concept. It was hard to wrap my mind around, but still incredibly fascinating. I wonder if it'll hold up 100 years from now.

Okay, but what REALLY freaked me out? There's a picture in here that SHOWS dark matter. I mean, okay, it just highlights the region in blue. But the fact that we can (sort of) detect it? That's crazy!

Doctor Moss says

When you are reading a big picture science book, it’s usually pretty easy to tell whether you are reading something written by a scientist or by a science writer. This one is written by a scientist.

J. Richard Gott gives a first-hand, participant account of the current state of the investigation of the large scale structure of the universe.

Gott is a very gifted topologist, as his high school science fair project on spongelike pseudopolyhedrons evidences. He later came back to those shapes as models for thinking about the shape of the universe.

He begins the books with some history — the debates that established some of the givens of the current debate, that we live in a spiral arm of one galaxy, in a universe of many, many galaxies, in a space that is expanding in every direction, from an initial Big Bang.

The question that Gott focuses on is what the topology of the largest structures in the universe is and how it got there. There are two main theories leading up to Gott's own contributions.

One is a "meatball" structure, championed by James Peebles and others. In this picture, galaxies form first, then cluster into larger structures, with voids between them. The universe is composed of these gravitationally-grown clusters and super-clusters surrounded by a sea of sparsely populated voids.

The opposing view was championed by the Soviet Yakov Zeldovich. In Zeldovich's picture, the voids formed first, expanding and pushing the masses that became the galaxies into thin pancake structures. The shape is analogous to swiss cheese, with large bubble-like voids among the dense masses of galaxies, clusters, and super-clusters.

Gott's own picture is informed by contemporary studies of how random quantum fluctuations influenced the initial expansion of the universe. Those very small fluctuations grow gravitationally via dark matter density into large-scale mass filaments, evolving into the galaxies and clusters of galaxies observable today. The structure that Gott finds is "sponge-like", with, unlike either the meatball or swiss cheese shapes, a symmetry between dense and sparse regions.

The sparse and dense regions together form a whole in which each comprises a continuous connected structure. You can travel, in principle, through all of the voids on a continuous path, or through all of the complementary dense regions, also on a continuous path. The two types of regions complement one another in complex but continuous mirrors of one another.

The story of course is much more complicated, and Gott takes us through some of the details. As a scientist, Gott excels at explanation at a relatively non-technical level. But I did find the levels at which he explains his topics to be uneven —on one hand explaining more than once why galaxies of the same size look differently sized depending on their distance, and on the other going pretty quickly through the explanation of exotic topologies like pseudopolyhedrons.

The final Chapter 11 extrapolates discoveries about the composition and dynamics of our universe into far distant future scenarios about the universe's fate. Those scenarios include relatively mundane ideas about the birth of bubble universes and more bizarre ideas such as Boltzmann Brains. It gets a bit speculative, but in a good way.

This isn't that easy a book, but if you want to see the development of current thinking about the shape of the universe from the vantage point of a participant, this is a great place to go. It can be challenging. It was to me, as neither a physicist nor a mathematician, but with some background in astronomy and cosmology. There are books more fitted to a general audience — this one fills a different niche.

Jafar says

So the universe is probably constructed like a sponge: cluster of galaxies connected to each other by filaments of galaxies that can be longer than a billions light years. The largest known structures in the universe. Except that no one knows how big the universe is. Or if ours is only one in an infinite of a multiverse. Still fascinating.

Adam says

Quite dense; not an easy read for non-scientists like myself. But, it was a fun challenge. It answered a lot of the questions I had ("how could they know that?...") when it comes to the age and nature of the universe. The book is laid out showing the history of the ways scientists have modeled the structure of the universe over the past 100 years. It ends with the latest ideas, and the questions being worked on right now.

Gianni Costanzi says

La ricerca della struttura dell'universo, per capirne le origini.

Ho comprato questo libro perché appassionato di astrofisica e perché non avevo mai letto nulla in merito alle grandi strutture rilevate su scale enormi nell'Universo visibile. E' impressionante capire (o quantomeno intuire) quello che negli ultimi decenni è stato scoperto in merito alla trama del nostro Universo, e quello che mi impressiona ogni volta è pensare alla scala dei fenomeni e delle strutture osservate, al fatto che guardando lontanissimo si guarda indietro nel tempo, fino a 13 miliardi di anni fa... strutture immense che permettono di comprendere come il tutto si è originato, strutture immense risultato di fluttuazioni quantistiche in un universo primordiale di dimensioni infinitesimali.. do 4 stelle al libro perché non l'ho trovato scorrevole e piacevole da leggere come altri libri divulgativi di Brian Greene (La Trama del Cosmo), Caleb Sharf (I Motori della Gravità, sui Buchi neri) o Jim Al-Khalili (l'affascinate La Fisica della Vita), ma potrebbe essere dovuto ad un mio limite che leggo non con lo scopo di studiare questa materia ma di affascinarmi (cercando comunque di "portare a casa" quanto più possibile). Comunque come avete forse potuto intuire, questa lettura mi ha lasciato affascinato, perché l'universo, infinitamente piccolo o infinitamente grande, non può che affascinare... allo stesso modo rimango affascinato dall'uomo, dagli studiosi e da dove riescono a spingere la propria mente e i propri studi dal nostro piccolo puntino nel cosmo fino agli orizzonti più lontani.

Dan Graser says

Extremely dense and detailed writing but ultimately worth it, so in other words - not quite on the level of traditional, "science for the layman," style books; definitely intended for a more specific audience but the work presented here is astonishing and ultimately illuminating. A fascinating glimpse into the process by which the large structure of our universe has been calculated and observed.

Letitia Todd Kim says

A fine book on a very specific topic: the observable universe’s topology (sponge-like with webs of higher density left over from early quantum fluctuations) and fate (possibly eternal expansion with baby inflationary universes springing forth to start anew). I gave it just 3 stars for purely selfish reasons: physical cosmology, it turns out, doesn’t interest me as much as philosophical cosmology, and the book is somewhat heavy on equations that will be meaningful only to advanced students of physics.

Kadri says

A look into how the large-scale structure of the universe was discovered, that gives attention to both the US and Soviet schools, brings out their differences clearly and continues beyond to 21st century.
The book does go more deeply into Gott's own part in it, but as a major contributor to the field, it's fine.
There were some detours that led a bit further away from cosmology (and were a great part to read), so you do come across two different styles of writing - one's more conversational and the other more precise and scientific and peppered with figures, symbols and graphs - the latter is great because you do get the details, and the former lets you take a deep breath before diving back into the depths of deep space.

It's not a difficult read as such, but I wouldn't recommend reading it as the first one about cosmology.

Manny says

The world we live in keeps getting bigger. Quite a long time ago, some smart people in Greece figured out roughly what the Earth looks like:

Admittedly they got a few details wrong, but that was eventually sorted out. Then, a bit less than two thousand years later, other people realized that the Earth was just one of a bunch of planets, that together with the sun made up our solar system:

Again, a few details needed to be corrected - it took a while to discover that there were rings around one of the planets, there were more planets than the six that had first been spotted, and there were all these weird little rocks between the fourth and fifth planets.

About a hundred years ago, our world once again expanded. The people who worked out what our solar system looked like had also concluded that the stars must be other suns, and that the vague glow that spread in a band across the sky was really a bunch of distant stars; evidently we lived in the middle of a huge cloud of them. Now, with better telescopes, it became clear that other vague glowing patches were similar clouds of stars, seen from a great distance. At least as far back as Kant's forgotten astronomy book, the *Universal Natural History*, there had been scientists and philosophers prepared to argue for this controversial idea. By now, we've all seen pictures of galaxies:

In 2016, everybody knows that we live on a planet, which is in a solar system, which is in a galaxy. So where is our galaxy? It's common knowledge that there are zillions of them dotting the space around the one we happen to live in. But what does geography look like on the intergalactic scale? That's sort of the central question Richard Gott's book is exploring, and I was embarrassed to find that I didn't know. It wasn't like I was completely ignorant. I was aware that our galaxy was part of a collection imaginatively called "The Local Group". And I'd read that galaxies often congregated in "sheets" or "filaments". All the same, what was the next picture in the sequence?

Well, having finished the book, I'm better informed, and there turns out to be a satisfyingly elegant answer. It's easy to get confused, since you need to be careful about just which question you're asking. A straightforward way of looking at it is to draw a three-dimensional map of the space around us, which is something like this:

But the random-looking collection of blobs above misses the essential point. What the map shows us is the parts of space where there's a lot of stuff. Well, of course, you may protest: what else would it show? From our very small-scale point of view, it seems like the only possible way to think. Our solar system is mostly empty space, with some planets floating in it. Our galaxy is even emptier space, with some stars, gas and black holes floating in it. A map ought to show where those things are. Right?

In fact, wrong! When we think about the whole universe, we *shouldn't* be thinking of it as mostly empty space with some objects scattered around here and there. One of the key discoveries that astronomers have made over the last twenty years is that the expanding universe created by the Big Bang is "flat"; it's exactly balanced on the knife-edge between a positively curved space, where gravity is stronger than expansion, and a negatively curved space, where expansion is stronger than gravity. This may sound boring and abstract, but in fact it leads to some very concrete consequences. Since the whole universe is poised on this knife-edge between expansion and gravity, it follows that each part of it was originally also close to being on the same knife-edge. The key word is "close". Some parts of the universe were very slightly denser than average, and gravity won to make them start contracting; other parts were very slightly less dense than average, and expansion won to make them start thinning out.

When astronomers began to study the geography of the universe, they noticed huge clumps of matter, like the ones in the picture above; they also noticed huge "voids", virtually empty spaces where there were next to no galaxies. At first, there was disagreement between the people who thought the clumps were the important thing (the "meatball soup model") and the people who thought the voids were the important thing (the "Swiss cheese model"). In fact, the flatness of the universe makes the situation symmetrical. If you draw maps of high-density regions - the "meatballs" - they are almost exactly the same as maps of low-density regions - the holes in the "Swiss cheese". When you plot the 50% contour, you find the low-density part of the universe has just the same kind of twisty three-dimensional shape as the high-density part. They both look like marine sponges, full of holes and passageways, and they interpenetrate each other in many places. A 50% contour map looks like the one below, where you can see that the solid part and the empty part each fill up roughly the same volume.

I'm afraid I've only given the merest sketch, and when you follow up the details you find the story spreads out in all kinds of fascinating directions. The crucial importance of dark matter and dark energy; how "inflation" during the first fraction of a second may have created the little density imbalances; the way gravitational lenses provide the data for cosmic cartographers; using topology to talk quantitatively about the shapes that arise. If I've managed to get you hooked, buy Richard Gott's book and find out more for yourself. I'm not exaggerating when I say it'll change your picture of the whole universe.

Daniele says

Un bellissimo libro divulgativo sulla cosmologia, che parla in particolare della struttura dell'universo, la "ragnatela cosmica" formata dai filamenti di galassie che collegano grandi ammassi, e della teoria inflazionaria, secondo cui nei primi istanti della vita dell'universo le sue dimensioni sarebbero aumentato di moltissimi ordini di grandezza. Alcune parti non sono semplicissime, rispetto ad altri libri divulgativi che ho letto su argomenti analoghi è un po' più difficile, ma nel complesso si riesce a seguire bene con un po' di impegno.

Jeremy says

I enjoyed this book quite a bit. I liked that it wasn't long, and instead got to the point without going through a bunch of twists and turns that weren't necessary. The book was particularly fascinating for me as I just spent my first summer working within the field of theoretical physics and cosmology, so I found the book to be right up my alley. I also find that the author explains concepts very well *without* simplifying them. It seems like so many science books water down the technical details to the point that everything is qualitative. That's not what you get here, and so I enjoyed the book a lot. The images were spectacular as well.

One thing I didn't like: all the footnotes were at the end of the book, so I didn't read them as I came across each footnote in the text since I didn't want to flip back and forth. It would have been nice to have them within the text (at the bottom of the page).

Xavier Shay says

Mind blowing. Struggled to keep my head above water in parts, despite the author really trying to make accessible. I blame that on my complete lack of familiarity with the subject. Overall got the gist of it. tl;dr THE UNIVERSE IS HUGE, but there is structure that we can understand.

Pat Hearps says

Took me a while to finish this - sometimes I could only absorb a few pages worth at a time, before having to stop and think about it! But don't let that scare you - it's actually pretty well written for a non-physicist audience. Gott uses some good metaphors and visual thought-experiments to explain a lot of the scientific concepts - but he packs a lot of information into this short book so sometimes those metaphors are milked for everything he can get out of them.

It mainly covers how a community of scientists came up with our current understanding of the large-scale structure of the universe - it's all about how galaxies form clusters along filaments with large voids in between. That sentence doesn't really do it justice though - it's the story of how they came up with mind-blowing simulations like this: https://www.youtube.com/watch?v=74Isy... which show what our universe looks like on the very large scale. I kept on having to remind myself the whole way through the book, especially whenever there were diagrams, that the individual data points or dots they are talking about are entire galaxies, not individual stars.

Early on he tells the story of how astronomers around a century ago started getting the first data indicating the universe was much, much bigger than anyone previously thought. It follows a familiar pattern for scientists writing books on their subject matter - a bit of history and context of the field, laying groundwork for the uninitiated, part-autobiography, but it's not all about his own work - he does a very good job of giving credit to many different people who have made contributions along the way.

A particularly interesting angle is how the more correct model of the universe actually came out of Soviet scientists. But because they usually only published in Russian, and the same physicists doing this astronomy also were involved in the Soviet nuclear program and not allowed out of the country, there was a delay in their ideas reaching the west, the author was one of the early people to open up communications with them.

I found it interesting the way he deals with dark energy - in a number of podcasts I have listened to, physicists talking about dark energy have been hesitant to say much more than "dark energy is a property of empty space making our universe expand faster than we can explain, but we don't know what it is or why it's there", and I haven't come across many explanations willing to state much more detail than that. Gott pretty casually explains that it is a non-zero positive energy state of vacuum space - i.e. even empty space has incredibly small yet finite and positive energy associated with it, not zero. He then goes on to discuss the implications of this for the future evolution of the universe in some pretty trippy ways. Granted, he doesn't seem to put forward any reasons as to why dark energy is there - he seems to just see it as a property of our universe similar to other scientific constants.

All up I found this a very enjoyable read, and it is truly mind-boggling to think about filaments of galaxies across the universe - there is a huge sensation of awe and wonder just thinking about it. It added a lot to my amateur understanding of cosmology and astrophysics - while I won't claim to have understood everything presented, I feel like I got enough of it to appreciate the subject matter. I might have to re-read sometime.

Galen Weitkamp says

The Cosmic Web: Mysterious Architecture of the Universe by J. Richard Gott.

Review by Galen Weitkamp.

In 1986 Margaret Geller, Valerie de Lapparent and John Hulchra published a map of a wedge shaped sector of the universe 730 million lightyears deep, 120 degrees wide and only 6 degrees thick. Almost every one has come across this map somewhere: in a newspaper, a magazine, a book or a lecture. It shows a universe that is not homogeneous on this scale but rather one that is filled with structures composed, not of single galaxies, but clusters of galaxies woven into superclusters that stretch like a glistening web over the black meadow of the cosmos. Deeper and more detailed surveys followed in 1989 revealing The Great Attractor and The Great Wall. Since then the Wilkinson Microwave Anisotropy Probe (WMAP) and the Sloan Digital Sky Survey (SDSS) have been revealing even more of the large scale structure of our universe.

Uncovering, describing and understanding this structure has been and is the life work of J. Richard Gott, professor of astrophysics at Princeton and the author of The Cosmic Web. Is the universe a giant Swiss cheese whose structures are suitably described as the negative space of giant bubble like voids? Or are the strands of luminous matter we see the negative space of a porous sponge of bubbles and tunnels? What's the difference? The negative space of a swiss cheese is a scattering of distinct bubbles, whereas the negative space of a sponge is another sponge. To see the latter imagine filling all the voids in a sponge with a liquid cement. After the cement hardens remove the sponge and what is left over has the shape of another sponge.

Gott's work and that of many others over the past decades decides in favor of the sponge. Moreover it would seem this spongey structure is the natural effect of expansion on initially random fluctuations in the distribution of mass/energy in a very early cold dark matter universe.

The Cosmic Web is written for the interested layperson. There are no mathematical formulae to worry the reader, but it is full of solid physics, detailed explanations, enlightening metaphors and entertaining histories.
