EXCERPTED FROM

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A NEW KIND OF SCIENCE

SECTION 9.6

The Nature of Space

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In the effort to develop an ultimate model for the universe, a crucial first step is to think about the nature of space—for inevitably it is in space that the processes in our universe occur.

Present-day physics almost always assumes that space is a perfect continuum, in which objects can be placed at absolutely any position. But one can certainly imagine that space could work very differently. And for example in a cellular automaton, space is not a continuum but instead consists just of discrete cells.

In our everyday experience space nevertheless appears to be continuous. But then so, for example, do fluids like air and water. And yet in the case of these fluids we know that at an underlying level they are composed of discrete molecules. And in fact over the course of the past century a great many aspects of the physical world that at first seemed continuous have in the end been discovered to be built up from discrete elements. And I very strongly suspect that this will also be true of space.

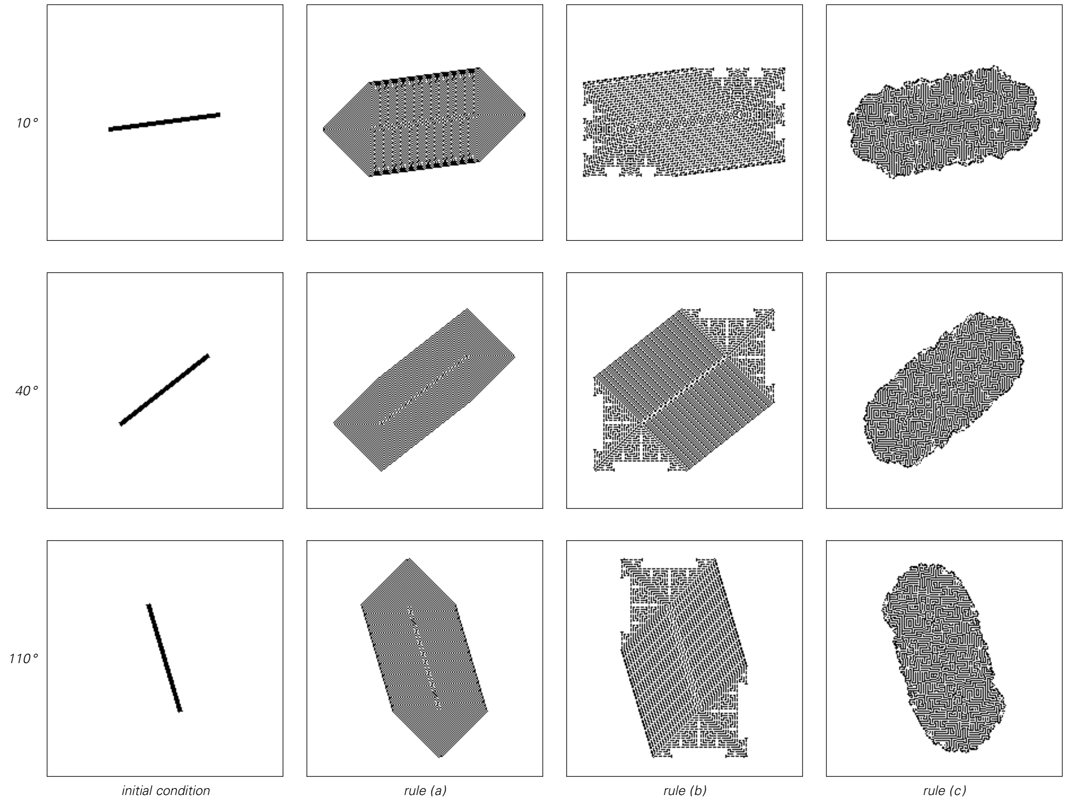
Particle physics experiments have shown that space acts as a continuum down to distances of around 10^{-20} meters—or a hundred thousandth the radius of a proton. But there is absolutely no reason to think that discrete elements will not be found at still smaller distances.

And indeed, in the past one of the main reasons that space has been assumed to be a perfect continuum is that this makes it easier to handle in the context of traditional mathematics. But when one thinks in terms of programs and the kinds of systems I have discussed in this book, it no longer seems nearly as attractive to assume that space is a perfect continuum.

So if space is not in fact a continuum, what might it be? Could it, for example, be a regular array of cells like in a cellular automaton?

At first, one might think that this would be completely inconsistent with everyday observations. For even though the individual cells in the array might be extremely small, one might still imagine that one would for example see all sorts of signs of the overall orientation of the array.

The pictures below show three different cellular automata, all set up on the same two-dimensional grid. And to see the effect of the grid, I show what happens when each of these cellular automata is started from blocks of black cells arranged at three different angles.



Examples of orientation dependence in the behavior of two-dimensional cellular automata on a fixed grid. Three different initial conditions, consisting of blocks at three different angles, are shown. For rules (a) and (b) the patterns produced always exhibit features that remain aligned with directions in the underlying grid. But with rule (c) essentially the same rounded pattern is obtained regardless of orientation. The rules shown here are outer totalistic: (a) 4-neighbor code 468, (b) 4-neighbor code 686 and (c) 8-neighbor code 746. In cases (a) and (b) 40 steps of evolution are used; in case (c) 100 steps are used.

In all cases the patterns produced follow at least to some extent the orientation of the initial block. But in cases (a) and (b) the effects of the underlying grid remain quite obvious—for the patterns produced always have facets aligned with the directions in this grid. But in case (c) the situation is different, and now the patterns produced turn out always to have the same overall rounded form, essentially independent of their orientation with respect to the underlying grid.

And indeed what happens is similar to what we have seen many times in this book: the evolution of the cellular automaton generates enough randomness that the effects of the underlying grid tend to be washed out, with the result that the overall behavior produced ends up showing essentially no distinction between different directions in space.

So should one conclude from this that the universe is in fact a giant cellular automaton with rules like those of case (c)?

It is perhaps not impossible, but I very much doubt it.

For there are immediately simple issues like what one imagines happens at the edges of the cellular automaton array. But much more important is the fact that I do not believe in the distinction between space and its contents implied by the basic construction of a cellular automaton.

For when one builds a cellular automaton one is in a sense always first setting up an array of cells to represent space itself, and then only subsequently considering the contents of space, as represented by the arrangement of colors assigned to the cells in this array.

But if the ultimate model for the universe is to be as simple as possible, then it seems much more plausible that both space and its contents should somehow be made of the same stuff—so that in a sense space becomes the only thing in the universe.

Several times in the past ideas like this have been explored. And indeed the standard theory for gravity introduced in 1915 is precisely based on the notion that gravity can be viewed merely as a feature of space. But despite various attempts in the 1930s and more recently it has never seemed possible to extend this to cover the whole elaborate collection of forces and particles that we actually see in our universe.

Yet my suspicion is that a large part of the reason for this is just the assumption that space is a perfect continuum—described by traditional mathematics. For as we have seen many times in this book, if one looks at systems like programs with discrete elements then it immediately becomes much easier for highly complex behavior to emerge. And this is fundamentally what I believe is happening at the lowest level in space throughout our universe.