

Dear Leonard Susskind:

I learned most of what I know about the mathematics of general relativity from your lectures, not to mention other lectures, and I believe that I have found a way of making sense of the equations used in general relativity that goes beyond what you explained in your lectures. Since you always tried to make as much sense of them as possible, I want to tell you about a more radical way of explaining what corresponds to them more completely.

It is a radical solution to problems in modern physics because it starts with an explanation of mathematical truth. Physics is based on the methodological assumption that mathematically formulated laws of nature are the deepest possible empirical knowledge about the natural world, and it has flourished for centuries using careful measurements to confirm—or falsify—its predictions. In 1959, Eugene Wigner famously wondered about the “unreasonable effectiveness” of mathematics in discovering laws of physics, and he concluded that it was a miracle that we neither understand nor deserve. But I believe that its miraculous appearance comes from the assumption that mathematics is known independently of what perception finds in the world. And I believe that the assumption that mathematics known by a faculty of rational intuition is what causes the problems of modern physics. So, the first step in solving them is to explain the truth of mathematics by its correspondence to the natural world.

That is possible for naturalists because they believe that the natural world is made up of objects in space that exist independently of one another. Instead of assuming that the basic branch of science discovers mathematically formulated laws of nature, they can try basing science on the belief that the natural world is constituted by substances and infer the kinds of substances that constitute the natural world as the best explanation of what is found in the world, starting with

the “unreasonable effectiveness” of mathematics in discovering laws of physics. You should not object to this, since you say that you want to get along with as few abstract entities as possible.

By *substances*, I mean what the pre-Socratic philosophers agreed in the end about the nature of the first cause. They held that the natural world is constituted by self-subsistent entities with definite ways of existing in themselves as they endure through time, and they expected to explain everything in the world by showing how it is constituted by them. That would explain not only the kinds of *things*, but also their existence. Since *ontology* is the study of existence, it is fitting to call substances *ontological causes*, and the pre-Socratics were ontological naturalists. They never agreed about the kinds of substances that constitute the world, but contemporary ontological naturalists can, because what *they* find in the natural world includes the mathematically formulated laws that physics has discovered over the past few centuries. I predict that they will infer that the kinds of substances constituting the natural world include space as well as matter because correspondence to them is the best ontological explanation of the truth of mathematics.

In a world constituted by substances, change is constituted by their interactions, so regularities about change can be explained by the powers that enable them to interact with one another. The kinds of regularities that can be generated by interactions of space and matter are constrained by their essential natures, and since every regularity that their interactions can generate is quantitative, that explains why mathematics corresponds to the world. Space has an intrinsic geometrical structure as it exists independently of matter, so it explains why Euclidean geometry corresponds to the natural world. Arithmetic can be explained by rules for counting things with a distinct existence, including units of

space and time, so if matter has an intrinsic quantity (measurable by units) as it exists independently of space, all the properties of what is found in the natural world would be quantitative. That is, bits of matter coinciding with parts of space would have definite quantities, and assuming that species of bits of matter are defined by the (spatio-temporal) geometrical structures of their correspondence with parts of space, all regularities about change generated by the interactions of space and matter would necessarily be quantitative.

If that is why mathematics is so “unreasonably effective” in discovering laws of nature, it is possible that space and matter have more specific powers that enable their interactions to generate the regularities described by laws of physics. Discovering those powers would not only confirm this ontological explanation of the truth of mathematics, but also solve the problems of modern physics. Since our ordinary way of understanding the natural world includes geometry and counting, there would be nothing puzzling about what corresponds to the laws of physics, and that would solve the problems of physics.

What is more, this way of reducing physics to ontology could expose the basic cause of intractable problems in quantum physics. Though physicists can use mathematics as a language for describing regularities about change because they are all quantitative, the way that they use mathematics could hide some regularities from physics. Space acts on matter by giving bits of matter spatial relations, its role as the container of matter is represented by the use of coordinate systems to describe how they move and interact. But if space and matter *inter-act*, bits of matter can also act on space in ways that affect other ways that space acts on matter, and their omission could be what causes problems in modern physics. *Those* roles of space in helping matter

generate regularities about change cannot be described by equations that use coordinate systems to describe how bits of matter move and interact. For example, some ways that space acts on bits of matter besides giving them spatial relations could be the long-suspected hidden variable that explains the probabilistic character of quantum laws as just an appearance. It could not, in principle, be described by a mathematically formulated law of physics.

By the way, the kind of interaction of space and matter, or *ontological mechanism*, used to explain the laws of quantum physics may interest you because it explains something that you confessed baffled you. In a lecture on modern physics, you said that every time you wrote the Lagrangian equation on the white board, you were puzzled by its similarity to the equation for the conservation of energy. If the total energy of a closed system is the sum of its kinetic and potential energy, how could the difference between them be used to formulate a principle of least action from which equations of motion could be derived? This was a valuable moment for me because the ontological explanation of the laws of classical physics explains energy as the quantity of matter, and since it explains electromagnetic forces by what I call the *fueling model of acceleration*, I realized that this ontological mechanism explained why the principle of least action entails equations of motion. Descriptions of what happens in terms of energy abstract from time, but when acceleration is explained as a flow of matter, it is obvious that the rate of flow required for a given acceleration depends on its velocity. The faster a particle moves, the more space it covers per unit time, and so when field matter (potential energy) is spread evenly in space, the more field matter a particle must absorb (and turn into kinetic energy) per unit time to accelerate at a constant rate. And the reverse for deceleration. Thus, since action is the total quantity of matter in a closed system added up per unit time, it is the extremum that determines

how particles move and interact. The fueling model is a way of thinking outside the mathematical box of physics that reveals the causal relevance of time.

This is the basic structure of the ontological mechanism I use to explain the laws of quantum physics, called the *inertial system*, and in the ontological explanation of Einstein's law of gravitation, the inertial system is just part of an all-encompassing ontological mechanism I call the *gravitational system*. But to play its role, the inertial system must explain the regularity described by Einstein's special theory of relativity (by following H. A. Lorentz and using deformations of material bodies caused by their motion relative to space to explain the undetectability of absolute velocity). Since the Lorentz transformation is described mathematically by the equation that Minkowski used to construct his spacetime diagram, this shows how points in a 4-D Riemannian manifold correspond to interactions of space and matter as they endure through time. The gist of the ontological explanation Einstein's general theory of relativity is that curved spacetime corresponds to the acceleration of the inertial system (and all the matter interacting with space in it) in a Newtonian gravitational field (because points in the gravitational field are moving relative to the inertial system and suffering Lorentz deformations).

Ontological mechanisms for laws of physics of all kinds are presented in some quantitative detail in the *Unification of Physics*, the first volume of a trilogy, called *Naturalistic Reason*, that I am now self-publishing as I send you this message. The ontological reduction of gravitational physics shows that the non-locality of quantum entanglement evident in Bell Inequality experiments can be explained by how space interacts with bits of matter everywhere in the universe at once. This reduction of quantum physics to ontology includes an explanation of all the particles described in the Standard

Model, and though I have not tried to understand the mathematics of string theory, I would not be surprised if it corresponds in some interesting ways to equations used in string theory. In any case, this reduction of physics to ontology will overcome the most pressing problem of theoretical physics, the mathematical disparity between quantum and gravitational physics, because all the regularities described by those laws are generated by interactions of the same two substances everywhere in the universe. And by the way, it implies that there is a way of measuring absolute velocity, which may be possible in few years with space-based LIGO.

No one, to my knowledge, has tried to explain the laws of physics in this way. But I should mention that it is just part of what follows from the discovery that space is a substance that interacts with matter. The second volume of *Naturalistic Reason*, the *Unification of Science*, shows how the reduction of physics to spatio-materialism reveals a kind of efficient cause, not recognized by physics, called *geometrical causes*, and shows how specialized sciences use it to explain the regularities they study completely enough to discover that evolution brings beings like us into existence on suitable planets throughout the universe. The third volume, the *Unification of Science and Philosophy*, shows how consciousness can be part of a world constituted by matter and space, and it shows how ontological scientists will use an illusion inherent in consciousness to trace the origin of ontological science to an exchange of metaphysical arguments in Western civilization that causes a distinct stage in the evolution of life and turn science into naturalistic reason.

All these predictions are justified in enough detail to cause the scientific revolution that they predict. But they all depend on the reduction of physics to ontology, and so your response

as a physicist is critical. But you will naturally be skeptical because it is hard to believe that anyone has found powers of space and matter that enable their interactions to explain the laws of quantum physics. That is, however, what I believe that I have found, and since you will wonder about anyone who makes such an unlikely claim, let me say something about myself and its origin. I have been working on this argument, pretty much on my own, for over 45 years, while teaching philosophy at American University for 30 years and since retiring from teaching over 20 years ago. (That is when I learned enough from you to figure out the equations of general relativity correspond to the spatio-material world.) As a philosopher, I have written this argument with a care that justifies expecting it to stand up under such scrutiny. There may be incomplete or mistaken arguments in it. But I am confident that the discovery that space is a substance that interacts with matter will eventually cause the scientific revolution I predict, and I am prepared to defend it on all fronts. My reason for writing you and a few others is to make what I have discovered public. I am about to turn 83, and I believe that it is my duty to tell others about my discoveries because my society has given me the leisure and privilege to enjoy a life spent in such an exceedingly meaningful way.

But even those who take arguments seriously will find the prospect of reading a detailed all-inclusive explanation of the natural world in three volumes daunting. So, I am offering an easier way of learning more about it. An executive summary of the entire argument is presented in a short (150 page) book titled *Sapere Aude* that I am also self-publishing now. It has three parts, and since the first chapter of each part is about physics, you will find what you need in it. I am including a free Amazon link to an eBook version of it. (See below.) And there is more information about this argument at natReason.com, including an introduction to the trilogy, a Table of Contents for it, a bookstore, and more information

about me. I would be happy to answer any questions you may have and very grateful to learn about any problems that you think may cast doubt on it. You can reach me personally at phillipscribner@yahoo.com.