

*The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next* by Lee Smolin is an interesting book. On pages 14 and 15 he writes about dark matter/dark energy.

Over the last decades, astronomers have done a very simple experiment in which they measure the distribution of mass in a galaxy in two different ways and compare the results. First, they measure the mass by observing the orbital speeds of the stars; second, they make a more direct measurement of the mass by counting all the stars, gas, and dust they can see in the galaxy. The idea is to compare the two measurements: Each should tell them both the total mass in the galaxy and how it is distributed. Given that we understand gravity well, and that all known forms of matter give off light, the two methods should agree.

They don't. Astronomers have compared the two methods of measuring in more than a hundred galaxies. In almost all cases, the two measurements don't agree, and not by just a small amount but by factors up to 10. Moreover, the error always goes in one direction: There is always more mass needed to explain the observed motions of the stars than is seen by directly counting up all the stars, gas, and dust.

There are only two explanations for this. Either the second method fails because there is much more mass in a galaxy than is visible, or Newton's laws fail to correctly predict the motions of stars in the gravitational field of their galaxy.

All the forms of matter we know about give off light, either directly as in

starlight or reflected from planets or interstellar rocks, gas and dust. So if there is matter we don't see, it must be in some novel form that neither emits nor reflects light. And because the discrepancy is so large, the majority of the matter in galaxies must be in this new form.

Today most astronomers and physicists believe that this is the right answer to the puzzle. There is missing matter, which is actually there but which we don't see. This mysterious missing matter is referred to as *dark matter*. The dark-matter hypothesis is preferred mostly because the only other possibility—that we are wrong about Newton's laws, and by extension general relativity—is too scary to contemplate.

Things have become even more mysterious. We have recently discovered that when we make observations at still larger scales, corresponding to billions of light-years, the equations of general relativity are not satisfied even when the dark matter is added in. The expansion of the universe, set in motion by the Big Bang some 13.7 billion years ago, appears to be accelerating, whereas, given the observed matter plus the calculated amount of dark matter, it should be doing the opposite—decelerating.

Again, there are two possible explanations. General relativity could simply be wrong. It has been verified precisely only within our solar system and nearby systems in our own galaxy. Perhaps when one gets to a scale comparable to the size of the whole universe, general relativity is simply no longer applicable.

Or there is a new form of matter—or energy (recall Einstein’s famous equation  $E = mc^2$ , showing the equivalence of energy and mass)—that becomes relevant on these very large scales: That is, this new form of energy affects only the expansion of the universe. To do this, it cannot clump around galaxies or even clusters of galaxies. This strange new energy, which we have postulated to fit the data, is called the *dark energy*.

Smolin makes the statement that general relativity has been verified precisely only within our solar system and nearby systems in our own galaxy. The existence of gravitational lens and other phenomena such as the precession observed in certain double- star systems where one of the stars is a regularly pulsating star of some sort, tends to cast doubt on that statement.

If there is dark matter in or around our solar system would the explanation of the anomalous precession of the perihelion of Mercury provided by general relativity be necessary? The question is especially relevant because there may be 6 times as much dark matter as ordinary matter. It seems the only way the Newtonian laws of gravity could be correct in our solar system is if our solar system had no significant amounts of dark matter. But, if hundreds of surrounding galaxies are purported to have very significant quantities of dark matter, how likely is it that our solar system has

no significant dark matter. If dark matter is needed to explain the motions of stars in hundreds of other galaxies, why does dark matter have no effects on the motions of the planets in our solar system?

One of the postulates of general relativity is that the mass of the universe is equally distributed throughout the universe. If dark energy cannot clump around galaxies or even clusters of galaxies as Smolin suggests, is it still reasonable to accept that postulate. The postulate was formed under the assumption that the mass of the universe was composed of ordinary matter which appeared to be uniformly distributed throughout the universe.

Is it scientific to invent an entirely new form of matter and an entirely new form of energy in order to keep empirical observations from falsifying a theory, especially if these new forms of matter/energy must now account for 96% of the universe? There is no direct empirical evidence for dark matter or dark energy. Without direct empirical evidence, isn't this just sophisticated junk science.