String theorist explores dark energy and our unique 'pocket' of the universe

February 18 2005

Some celestial bodies are so cold that methane freezes; others are so hot that nuclear reactions occur. And then there's Earth, with a benign temperature hovering in the narrow range between freezing and boiling, allowing the existence of liquid water-and life.
"There's no question that there are many things about the [universe] which if they were very much different, even just a little bit different, life couldn't exist, intelligent life couldn't exist," said Stanford physics Professor Leonard Susskind, who is currently on sabbatical and writing a popular book titled The Cosmic Landscape. "The [universe] is truly an incredibly fine-tuned place."

Dark energy-a mysterious force that causes matter to accelerate away from other matter-is a case in point. It fuels the expansion of our universe, but it's an oddly small force. But if it were bigger and caused matter to fly apart any faster, you would not be here to read these words.

On Feb. 18, Susskind will speak about dark energy in Washington, D.C., at the 2005 meeting of the American Association for the Advancement of Science. Other participants will include Sean Carroll and John Carlstrom, both of the University of Chicago, Adam Riess of the Space Telescope Science Institute, Licia Verde of the University of Pennsylvania and Georgi Dvali of New York University. They will relay how cosmologists are observing supernovae, galaxy clusters, large-scale structures and the cosmic microwave background to better understand the nature and evolution of dark energy. In addition, they will investigate dramatic new ideas about space and time to answer deep questions raised

by dark energy's very existence.

Dark energy doesn't just exist-it dominates. Only 5 percent of the universe is ordinary matter. Another 25 percent is dark matter-matter that scientists cannot "see" but whose existence is suggested because of the effects of its gravity on the rotation and clustering of galaxies. A whopping 70 percent of the universe is dark energy.

As the world's most famous physics equation, E = mc^2, shows, energy and matter are related. When the universe expands, the particles of matter dilute, or take up less space in a given volume. Ordinary energy, therefore, dilutes when the universe expands.

In contrast, dark energy-also called vacuum energy-is a property of empty space. When empty space expands, it just replaces itself with more empty space; it does not dilute. So dark energy is a form of energy that does not dilute as the universe expands.

"Eventually when the universe expands enough, all that will be left is the dark energy," Susskind predicts.

Enter string theory

Dark energy has the effect of a kind of "anti-gravity," causing everything to repel from everything else. This force is inevitable in physicists' equations, but it's many, many, many orders of magnitude smaller than can be explained by standard theories.

Enter string theory, which Susskind and Yoichiro Nambu proposed in 1969. While we observe three dimensions of space and one of time, string theory posits 10 dimensions of space and one of time. The extra dimensions are balled up, or compactified, into dimensions too small to detect but whose structures are important to the laws of physics.

Describing compactified dimensions is complex-to say the least. "We have examples of systems in nature which have thousands of degrees of freedom," Susskind says, citing a molecule made up out of a thousand atoms. "How many energy levels, how many quantum states, does such a molecule have? The answer can be as high as 10^1000 [ten raised to the power of one thousand]-[there are] huge, huge numbers of possibilities for the ways the atoms organize themselves. In the same way, there are huge numbers of possibilities for the way that these-they're called compactification manifolds-organize themselves. And because there are so many ways, there are many, many energy levels. For the molecule, there are many, many possible values for the energy, 10^500 [ten raised to the power of five hundred] possible values of the vacuum energy."

Dark energy poses great challenges and opportunities in physics and cosmology and may hold the key to the long-sought unification of quantum mechanics and gravity, Susskind says. "We're largely just beginning to get an overall view of how string theory and [the] incredibly many possibilities that appear to be inherent in it, are changing our view of what's natural, what's possible, what's probable."

Do 'pocket universes' exist?

In recent years, some physicists have suggested that rather than having one universe with one set of physical laws, string theory may lay the foundation for the possibility of the existence of innumerable "pocket universes," each with their own landscape of physical laws.

"The word 'universe' is obviously not intended to have a plural, but science has evolved in such a way that we need a plural noun for something similar to what we ordinarily call our universe," Susskind explains. "Alan Guth coined the name 'pocket universe,' meaning a pocket of space, a region of space, over which the environment is uniform, the laws of nature are uniform, the constants of nature are

uniform, and that these pockets of space are more or less identifiable with the things that we used to call the Universe, with a capital U. So we now need a plural for the concept if we believe that space is filled like a crazy quilt of environments with different properties and different laws of physics."

Today, string theory has become a serious controversy even within the physics mainstream. The number of possible energy states-10^500 [ten raised to the power of five hundred]-inherent in string theory is "totally unexpected," Susskind says. "There was constantly a sense that there would only be one, or some very small number, of legitimate solutions of the theory. Ed Witten [a physicist famed for his mathematical prowess] worked very hard to show that there was only a very small number, and he failed-failed completely."

The dust isn't likely to settle soon. Says Susskind: "More and more as time goes on, the opponents of the idea admit that they are simply in a state of depression and desperation. More and more people are starting to think about this possibility. But it's been a major sea change in the attitudes of theoretical physicists. ... It means we have a mathematical framework to think about it. We have a basic set of precise concepts to think about it, and it means that in time we will know the truth."

Source: Stanford University

Citation: String theorist explores dark energy and our unique 'pocket' of the universe (2005, February 18) retrieved 2 May 2024 from https://phys.org/news/2005-02-theorist-explores-dark-energy-unique.html