Macro, not micro: modified theories of gravity

February 16 2007

When it comes to cosmology, the macro scale is important. As scientists search for the reasons behind the increasing rate at which the universe is expanding, they modify Einstein's theory of gravity and delve into dark energy theories to explain this counter-intuitive phenomenon.

These simple modifications are represented as f(R) theories, and they are used to explain what is seen on a cosmic scale. But there's a problem. "Some modified theories of gravity have nice features for cosmology, on the big scale, but they don't work so well on the small scale," Gonzalo Olmo explains to *PhysOrg.com*. "I managed to solve these equations on the micro level, and I found that they are inconsistent."

Olmo, 28, is a post-doc at the University of Wisconsin-Milwaukee. He says he solved these equations two years ago, but waited until interpreting them to have them published. His recent letter in *Physical Review Letters*, which puts forth the equations and their interpretations, is titled "Violation of the Equivalence Principle in Modified Theories of Gravity."

In the Letter, Olmo presents equations that suggest that when some modified theories of gravity are applied to the micro scale, new properties emerge that can effectively rule out some theories that explain accelerating universe expansion.

"If we manage to show these theories are not consistent, which it looks like, then this approach in cosmology would be useless," Olmo points out. He says that there are two main ways modified theories are studied: in the metric formalism or in the Palatini formalism. Olmo explains that his paper focuses on theories of gravity in the Palatini formalism. "[T]he connection is regarded as independent of the metric and, therefore, must be determined by solving its corresponding field equations," the paper says.

Olmo says that when he solved the equations on the micro scale, he noticed the emergence of new properties: "These new properties have never been seen in other modified theories of gravity, and these new properties are what make these theories so weird on the micro scale."

Even though Olmo says that these theories would not do to explain the expansion of the universe, since they are inconsistent on the micro scale, there are some uses for modified theories of gravity. He explains that the differences between how these modified theories work on the macro scale and on the micro scale could offer insight into the interaction between gravitation and quantum physics.

"According to Einstein," Olmo explains, "spacetime should be nearly flat in, for instance, your dining room or the interior of an atom." He pauses before continuing: "However, in Palatini theories we find that it is curved even on a micro level, which has a strong effect on the properties of the quantum world. This can lead to better understanding by seeing how these modified theories of gravity interact with quantum theory."

"There are different possibilities to the reasons behind the acceleration of the universe," continues Olmo. "Some theorists use dark energy to explain the expansion, and others modify the equations of gravity to say it is not dark energy. However, there could be a mix." He says that it is very difficult to distinguish the effects of dark energy from those of modified equations, and the difference could hold the key to discovering what's behind the increasing rate of expansion of our universe. And he thinks applying modified theories of gravity to the micro scale as well as to the macro scale could help determine the different effects. “If this idea can get going,” he enthuses, “there could be a very interesting future.”

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