Can R2 gravity explain dark matter?

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(PhysOrg.com) -- "In many ways, the standard model of cosmology works very well," Jose Cembranos tells *PhysOrg*. "However, there are very basic features that we just do not know. We have dark energy and dark matter. They dictate the evolution of late time cosmology. They both together constitute more than 95 percent of the energy content of the present Universe." If this is the case, why do we trust the standard model? It can't explain such a large portion of the universe.

Cembranos points this out about why we continue to place our faith in the standard model: "Sometimes it is hard to explain why you trust a model if you don't understand the most part of it. The reason is that you do not need to know the fundamental nature of dark energy or dark matter to compute the evolution of the Universe. With the ingredients we have, the model fits the different observations we have done so far." But many scientists are not satisfied with a model that leaves out the natures of dark energy and dark matter. They, like Cembranos, are looking for ways to modify the standard model so that these mysterious parts of the universe may eventually be revealed.

Cembranos is a scientist at the William I. Fine Theoretical Physics Institute at the University of Minnesota in Minneapolis. He has been working on a model of cosmology that includes a modification of Einstein gravity. "Gravity is the main issue in any model of cosmology; it is the force that drives the dynamic. However, we know that the Einstein theory of gravity cannot be the final word on gravity. It is not consistent at high energies." Cembranos has developed a model that uses an effective approach and illustrates the idea that new gravitational states could account for dark matter with R^2 gravity. His work is described in Physical Review Letters: “Dark Matter from R^2 Gravity.”

“I used R^2 gravity because it is the simplest way to modify Einstein gravity,” Cembranos explains. “We know how to deal with gravity as an effective field theory, working at low energies. At low energies you have the opportunity for a perturbative expansion, everything working order by order. Unfortunately, you can’t go to very high energies. From a quantum standpoint this approach does not work.”

“In addition to a constant that may explain the dark energy, and a linear term in the space-time curvature that defines Einstein gravity, the next term of the expansion is quadratic,” Cembranos explains. “When you introduce this R^2 term, gravity is modified by the introduction of a new mediator of the gravitational interaction. However, it is completely different from its cousin: The standard graviton predicted by the linear term is a mass-less particle of spin 2. This new graviton has mass and spin 0.”

The model that Cembranos developed also allows you to tune the parameters of the system in order to explain dark matter. “I wanted to focus on the dark matter issue,” he says, “because dark matter seems a little more straightforward. All you need to do is introduce more stuff into the model. We can do this with R2 gravity.”

Cembranos points out that while R2 gravity is an interesting approach to the problem, it doesn’t hold all the answers. “Many people have used different modifications of gravity in order to explain dark matter and even dark energy,” he says. “However, usually these explanations end up being worse than Einstein gravity. Einstein gravity clearly has problems, but nearly all the other explanations are worse.”

What makes the model studied by Cembranos more promising, he insists, is that using the R^2 term isn't worse than Einstein's gravity theory. "It's not any better, but it's also not any worse. It's more or less the same, but a little more complicated."

The additional gravitational states allowed in the R^2 gravity modification introduce new degrees of freedom to the standard model. "I'm hoping that by studying this model," Cembranos points out, "that we can get a general idea of what can be signals or observations that are apparent if dark matter is really related to the gravitational sector."

More information: Cembranos, Jose, "Dark Matter from R^2 Gravity." Physical Review Letters (2009). Available online: link.aps.org/doi/10.1103/PhysRevLett.102.141301 .