Russian scientists find flaws in popular theories of gravity

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Using a model of black holes, scientists from the Ural Federal university (UrFU, Yekaterinburg) determined that a popular theory of gravity that seemed to work perfectly at the cosmological level (a subclass of Horndeski theory) does not apply in the real world. They have published their results in *Classical and Quantum Gravity*.

Modern physics has accumulated a lot of prerequisites for the revision of general relativity, including the accelerated expansion of the universe, the presence of dark matter, and the impossibility of renormalizing gravity. All the fundamental interactions known to science have been described in quantum language except for gravitation. These small inconsistencies indicate that the theory of relativity is not the final theory of gravitation, but an approximation (a similar story occurred with Newton's theory). Theoretical physicists constantly propose extended theories of gravity, and these models need to be compared with observations.

One of the simplest versions of such an extended theory appears under the assumption that the gravitational constant (a fundamental physical quantity that is the same in time and at all points in the universe) is not a constant, but a field that can vary in time and space. Scientists cannot measure this slowly changing field with accuracy, and only therefore perceive it as a constant. This theory posits gravity with a scalar field (given only one number at each point). This is how the first and simplest theory of gravity with a scalar field, the Brans-Dicke theory, was formulated. This and similar theories are considered to be among the most promising ways of expanding General Relativity.

In her work, Daria Tretyakova, PhD from UrFU, together with her colleague from the University of Tokyo, explored one of these theories—the so-called Horndeski theory. The Horndeski framework gives the most general theory of gravity with a scalar field, without instabilities, and containing "healthy" physics—that is, without any unusual parameters of matter, for example, negative or imaginary mass.

At the cosmological level, a subclass of Horndeski models, which are symmetric with respect to the shift of the scalar field in space and time, have helped scientists describe the accelerated expansion of the universe without resorting to additional theories. These models were chosen for rigorous and comprehensive testing. The authors of the paper considered the Horndeski models at the astrophysical scale—the scale of individual objects of the universe—and determined that black holes (as real objects) turn out to be unstable in the models which previously successfully proved themselves in cosmology.

Consequently, these models are not suitable for describing the real universe, because black holes are currently believed to exist in space as stable objects. However, the scientists have proposed a way to construct Horndeski models that ensure black holes stability. The paper is a step toward a new theory of gravity that fulfills the requirements of modern physics. Now, the authors are planning to subject the newly proposed models to standard tests to check their adequacy at the cosmological and astrophysical scale.

More information: Daria A Tretyakova et al, Stable black holes in shift-symmetric Horndeski theories, *Classical and Quantum Gravity* (2017). [DOI: 10.1088/1361-6382/aa8057](DOI: 10.1088/1361-6382/aa8057)

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