Gravitational echo phenomenon will become a key to the new physics, physicist says

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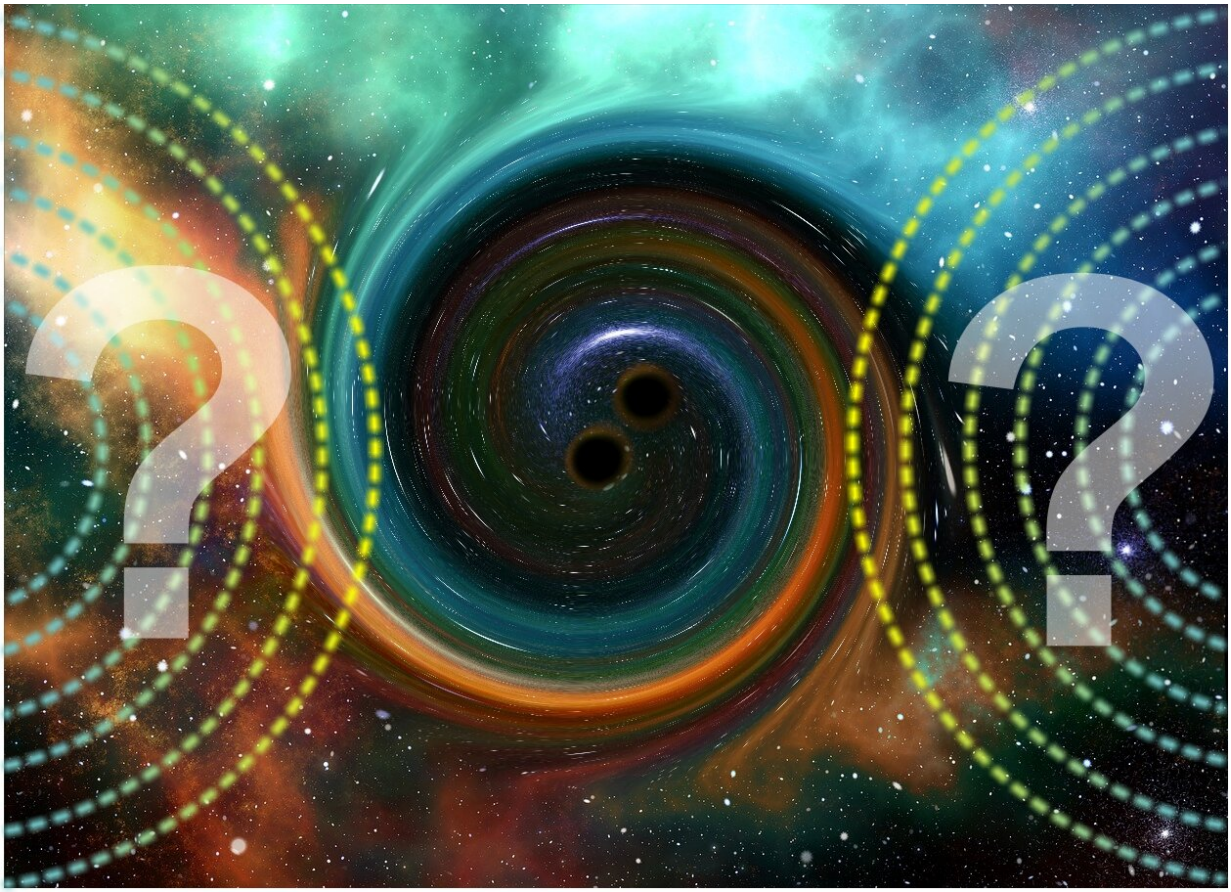

Credit: Natalia Deryugina

Gravitational echoes may be caused by the collision of two black holes, and may indicate that these objects have completely new physical

properties. This conclusion was made by RUDN physicists after a series of mathematical calculations. The scientists state that if the existence of the echo phenomenon is confirmed, astrophysicists would have to reconsider their view of compact space objects. The results of the study were published in *Physical Review D*.

According to the theory of general relativity (GR), any massive object distorts space-time. A similar effect is observed when a heavy metal ball is placed on stretched elastic fabric. The heavier is the ball, the deeper is the depression in the fabric. Similarly, the higher the mass of an object, the more it distorts space-time. Black holes are among the heaviest objects in the universe, and therefore distort space-time the most. When two black holes collide, gravitational waves spread out from the site of collision. They can be compared to rings on the water, or sound waves, but there is one important peculiar feature. Gravitational waves do not propagate spatially—they are themselves the oscillations of space-time.

Gravitational waves from the collision of two black holes decay with time, but on their final stage, they can cause the so-called echo—additional wave scattering. It can be compared to regular acoustic echo. The existence of such gravitational echo has not been confirmed yet, and there are different opinions about its possible source. A RUDN physicist, together with colleagues from the Czech Republic and Russia, assumed that if the existence of gravitational echo is experimentally confirmed, it would be the beginning of the new physics adding to GR.

Hypothetically, black holes may be influenced by adjacent massive objects, such as galactic nuclei, accretion discs, or clouds of matter. Previously, it was believed that gravitational waves may scatter on these objects and form echo. The authors of the study provided a mathematical proof that such objects cause very weak echo or none at all.

According to the calculations, for a conglomeration of matter to cause echo, its mass should be at least comparable to the mass of the black hole itself. However, there are usually no such heavy objects around black holes. If they were found, gravitational waves from such black holes would look differently even on the initial collision stages.

The second possible explanation might be specific boundary conditions on the surface of a black hole. To understand them, astrophysicists will have to reconsider their views on black holes, and it cannot be done within the existing GR framework.

"We demonstrated that if the echo is registered after the final stage of collision, it would indicate not the existence of a certain massive object near a black hole, but a set of new physical laws describing the surfaces of compact objects," says Roman Konoplya, a co-author of the work, and a research associate of the Training and Science Institute of Gravitation and Cosmology at RUDN.

More information: R. A. Konoplya et al. Echoes of compact objects: New physics near the surface and matter at a distance, *Physical Review D* (2019). DOI: 10.1103/PhysRevD.99.024007

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