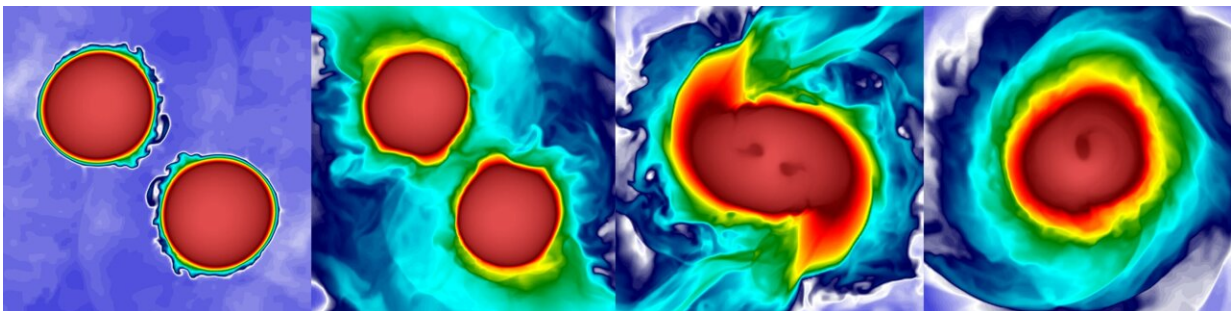


# Dark energy: Neutron stars will tell us if it's only an illusion

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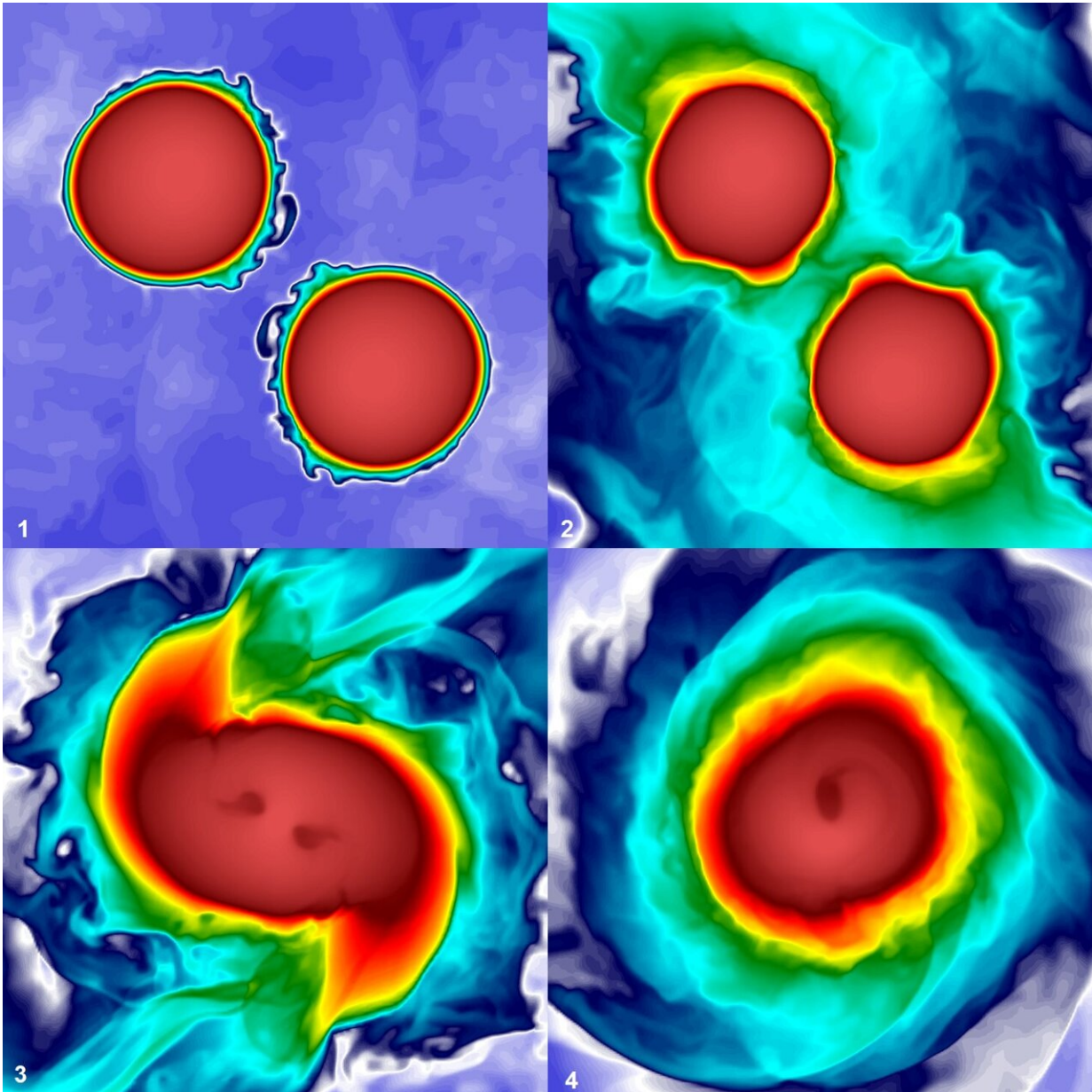
Simulated merger of a neutron star binary. Credit: Miguel Bezares—GRAMS group SISSA

A huge amount of mysterious dark energy is necessary to explain cosmological phenomena, such as the accelerated expansion of the Universe, using Einstein's theory. But what if dark energy was just an illusion and general relativity itself had to be modified? A new SISSA study, published in *Physical Review Letters*, offers a new approach to answer this question. Thanks to huge computational and mathematical effort, scientists produced the first simulation ever of merging binary neutron stars in theories beyond general relativity that reproduce a dark-energy like behavior on cosmological scales. This allows the comparison of Einstein's theory and modified versions of it, and, with sufficiently accurate data, may solve the dark energy mystery.

For about 100 years now, general relativity has been very successful at describing gravity on a variety of regimes, passing all experimental tests on Earth and the solar system. However, to explain cosmological observations such as the observed accelerated expansion of the Universe, we need to introduce dark components, such as [dark matter](#) and [dark energy](#), which still remain a mystery.

Enrico Barausse, astrophysicist at SISSA (Scuola Internazionale Superiore di Studi Avanzati) and principal investigator of the ERC grant GRAMS (GRavity from Astrophysical to Microscopic Scales) questions whether dark [energy](#) is real or, instead, it may be interpreted as a breakdown of our understanding of gravity. "The existence of dark energy could be just an illusion," he says, "the accelerated expansion of the Universe might be caused by some yet unknown modifications of general relativity, a sort of 'dark gravity'."

The merger of neutron stars offers a unique situation to test this hypothesis because gravity around them is pushed to the extreme. "Neutron stars are the densest stars that exist, typically only 10 kilometers in radius, but with a mass between one or two times the mass of our Sun," explains the scientist. "This makes gravity and the spacetime around them extreme, allowing for abundant production of gravitational waves when two of them collide. We can use the data acquired during such events to study the workings of gravity and test Einstein's [theory](#) in a new window."



Simulated merger of a neutron star binary. Credit: Miguel Bezares—GRAMS group SISSA

In this study, published in *Physical Review Letters*, SISSA scientists in collaboration with physicists from Universitat de les Illes Balears in Palma de Mallorca, produced the first simulation of merging binary

[neutron stars](#) in theories of modified gravity relevant for cosmology: "This type of simulations is extremely challenging," clarifies Miguel Bezares, first author of the paper, "because of the highly non-linear nature of the problem. It requires a huge computational effort—months of run in supercomputers—that was made possible also by the agreement between SISSA and CINECA consortium as well as novel mathematical formulations that we developed. These represented major roadblocks for many years till our first simulation."

Thanks to these simulations, researchers are finally able to compare general relativity and modified gravity. "Surprisingly, we found that the 'dark gravity' hypothesis is equally good as [general relativity](#) at explaining the data acquired by the LIGO and Virgo interferometers during past binary neutron star collisions. Indeed, the differences between the two theories in these systems are quite subtle, but they may be detectable by next-generation gravitational interferometers, such as the Einstein telescope in Europe and Cosmic Explorer in U.S. This opens the exciting possibility of using gravitational waves to discriminate between dark energy and 'dark [gravity](#)'," Barausse concludes.

**More information:** Miguel Bezares et al, No Evidence of Kinetic Screening in Simulations of Merging Binary Neutron Stars beyond General Relativity, *Physical Review Letters* (2022). [DOI: 10.1103/PhysRevLett.128.091103](#)

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