Fluidity in curved space-time

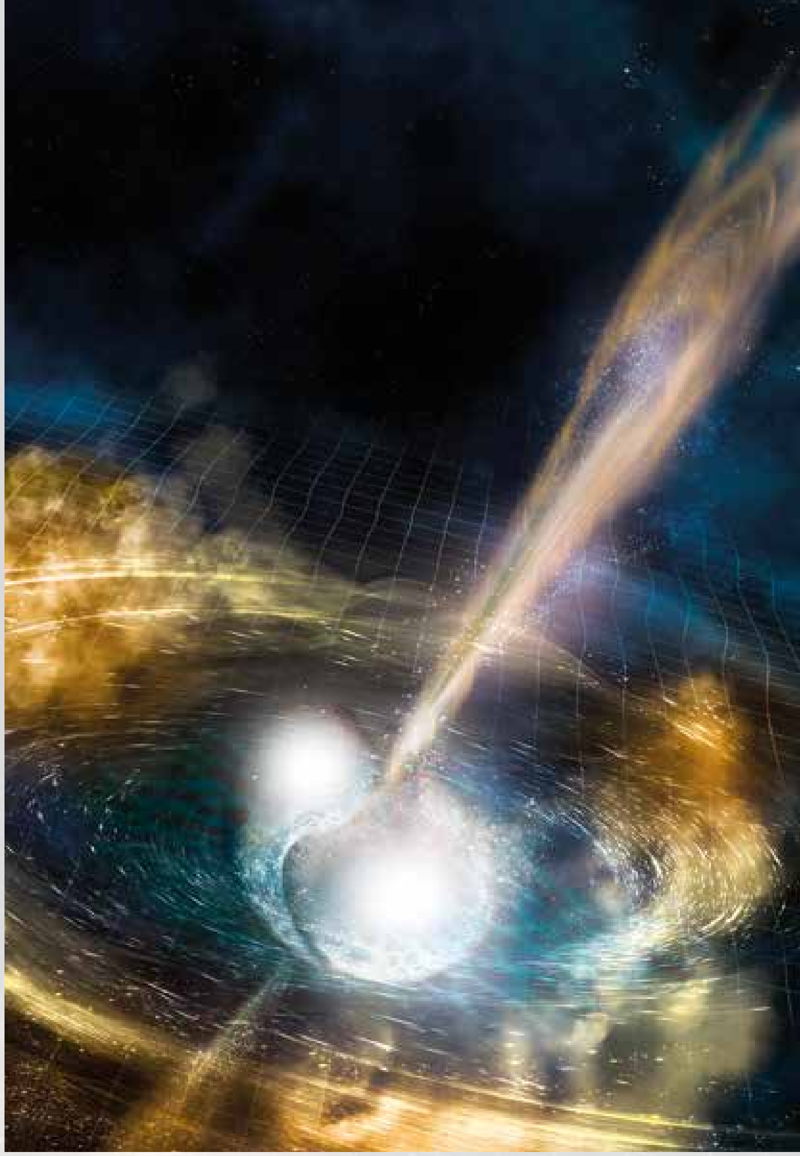

Illustration of two neutron stars merging, a scenario in which the Israel-Stewart theory explains the movement of viscous fluids

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Study supports theory on how dense matter interacts with strong gravitational fields

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In an article to be published in the journal *Physical Review Letters*, three Brazilian physicists have proven two of the mathematical theorems that support the Israel-Stewart theory, which was conceived in the 1970s to explain the behavior of viscous fluids—liquids, gases, or plasmas resistant to flow—moving at close to the speed of light and interacting with extremely strong gravitational fields. The researchers' calculations demonstrate the compatibility of the Israel-Stewart theory with Albert Einstein's (1879–1955) theory of general relativity, including for situations in which space-time is curved and ultradense matter is formed. An example of one such scenario is the collision and merging of two neutron stars, which are extremely compact and high-energy celestial bodies.

"Viscosity is a universal characteristic of all fluids that describes their resistance to flow, like when honey runs down the walls of a container. Similar phenomena also occur when neutron stars merge," explains Jorge Noronha, from the Institute of Physics at the University of São Paulo (IF-USP), one of the authors of the paper. "Although there was a general belief among the scientific community that the Israel-Stewart equations could be used to study this phenomenon, no one knew for sure before the publication of our paper if they were actually applicable to these cases," says study coauthor Marcelo M. Disconzi, from Vanderbilt University in Nashville, USA. The third author is Fábio S. Bemfica, from the Federal University of Rio Grande do Norte (UFRN).

Since the 1940s, many scientists have attempted to formulate a theory of viscous fluids compatible with Einstein's ideas. Their attempts, however, always encountered one problem: they violated the principle of causality, which is fundamental to the theory of relativity. Then, almost half a century ago, physicists Werner Israel, from Canada, and John Stewart (1943–2016), from England, appeared to have at least partially solved the problem with a theory that worked with relativity in certain situations. The solutions they proposed, however, appeared too simplistic to consistently predict the behavior of viscous fluids, considering that space-time can bend and form singularities at which matter and energy are compressed into a single point. "Our mathematical proof shows that the Israel-Stewart theory is robust enough to describe the movement of matter in this extreme scenario," says Noronha. ■

Project

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Scientific article

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