

Gravitational physics poised for new era of discovery

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In a paper recently published in the *Physical Review of Letters*, MSU Associate Professor of Physics Nico Yunes and two co-authors argue that LIGO's recent detection of gravitational waves just scratches the surface of what awaits to be discovered in the field. MSU photo by Kelly Gotham.

The recent detection of gravitational waves from the collision of two black holes signals a new era in gravitational wave astrophysics that will allow probing of the Universe in never before known ways, writes a Montana State University physicist in a recent scholarly paper.

MSU College of Letters and Science Associate Professor Nico Yunes is one of three co-authors on the paper published earlier this month in the prestigious *Physical Review Letters*. Yunes is one of the founders of MSU's eXtreme Gravity Institute, and he leads a research group in gravitational physics. He was recently awarded the General Relativity and Gravitation Young Scientist Prize by the International Union of Pure and Applied Physics and the International Society for General Relativity and Gravitation.

In February, an international group of researchers announced the first direct detection of gravitational waves – ripples in the fabric of spacetime – which are a direct consequence of Albert Einstein's 1915 General Theory of Relativity, using two enormous detectors in Livingston, Louisiana and in Hanford, Washington. The detectors, known as the Laser Interferometer Gravitational-wave Observatory, or LIGO, picked up waves coming from the merger of two [black holes](#) into one single, more massive black hole. News reports called it "the scientific discovery of the century."

In the paper published in the *Physical Review of Letters*, Yunes and co-authors – France's Centre National de la Recherche Scientifique, CNRS,

researcher Enrico Barausse and MSU undergraduate physics student Katie Chamberlain – argue that LIGO's detection just scratches the surface of what awaits to be discovered.

"Just as telescopes observe light at different frequencies, in analogy to different colors of the visible spectrum, future space-based gravitational-wave detectors are slated to observe at frequencies different than those at which LIGO operates, giving us insight into gravity during not just the merger of black holes, but also as they spiral closer and closer to each other before merging," Yunes said.

"Indeed, the planned European-led space-borne detector [eLISA \(the evolved Laser Interferometer Space Antenna\)](#) will detect some of the same sources as Advanced LIGO, but during a "younger" period of their evolution," Yunes added.

The eLISA project would put three satellites into space to create a triangular gravitational wave detector of a million kilometers or 621,000 miles per side. Each satellite would fire a laser at its companions to create the detection "sides" of the triangle. Because it is in space, eLISA would be able to detect gravitational waves at much lower frequencies, without being hindered by the seismic noise created by the constant shaking of the Earth surface that limits ground-based detectors such as LIGO. The complexity of the project puts the launch of the satellites sometime after 2030.

"The information contained in these sources opens up the possibility of multi-band gravitational wave astrophysics," Barausse said. Yunes and his co-authors demonstrated that these unique multi-band sources that will be observed both by LIGO and eLISA allow for unique and tremendously powerful tests of Einstein's theory.

"The combined observation of [gravitational waves](#) with LIGO and

eLISA would provide the most stringent verification to some of the main pillars of General Relativity," Barausse added.

If a violation of General Relativity is found through future observations, it would dramatically change physics, Yunes and his co-authors write.

"Just imagining the possibility that we will be able to test Einstein's theory 10 orders of magnitude more strongly than ever before gives me goosebumps," said Chamberlain.

"Such research, however, is only possible if the blueprint of the eLISA mission is not modified to cut down costs," Yunes added, which is currently being considered by the European Space Agency.

More information: Enrico Barausse et al. Theory-Agnostic Constraints on Black-Hole Dipole Radiation with Multiband Gravitational-Wave Astrophysics, *Physical Review Letters* (2016). [DOI: 10.1103/PhysRevLett.116.241104](https://doi.org/10.1103/PhysRevLett.116.241104)

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