University of Mississippi

eGrove

1-30-2019

Making Better Predictions of Black Hole Smash-Ups

Whitney Clavin
Caltech Strategic Communications

Follow this and additional works at: https://egrove.olemiss.edu/umnews

Ole Miss
UNIVERSITY OF MISSISSIPPI NEWS

Search this website ... | Search

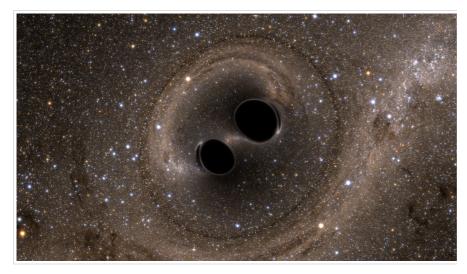**News Releases** | **UM COVID-19** | **Video Gallery** | **University Communications** | **Ole Miss Homepage** | **Ole Miss News Blog**

Making Better Predictions of Black Hole Smash-Ups

Caltech, UM physicists use supercomputers and AI to create most accurate model of stellar mergers

JANUARY 30, 2019 BY **WHITNEY CLAVIN/CALTECH STRATEGIC COMMUNICATIONS**

This simulation depicts two merging black holes, each about 30 solar masses. This is approximately what a person would see if they could travel in spaceship to take a closer look at merging black holes. Graphic courtesy the Simulating eXtreme Spacetimes project

OXFORD, Miss. – One of the most cataclysmic events to occur in the cosmos involves the collision of two black holes. Formed from the deathly collapse of massive stars, black holes are incredibly compact – a person standing near a stellar-mass black hole would feel gravity about a trillion times more strongly than they would on Earth.

When two objects of this extreme density spiral together and merge, a fairly common occurrence in space, they radiate more power than all the stars in the universe.

"Imagine taking 30 suns and packing them into a region the size of Hawaii," said Vijay Varma, a graduate student at the California Institute of Technology. "Then take two such objects and accelerate them to half the speed of light and make them collide. This is one of the most violent events in nature."

In a new study in the Jan. 11 issue of the journal Physical Review Letters, Varma and his colleagues – including **Leo Stein**, assistant professor of **physics and astronomy** at the **University of Mississippi** – report the most accurate computer model yet of the end stage of black hole mergers, a period when a new, more massive black hole has formed.

The model, which was aided by supercomputers and machine-learning, or artificial intelligence tools, will ultimately help physicists perform more precise tests of Einstein's general theory of relativity.

"Einstein replaced our understanding of gravity with the new idea that space and time themselves are curved," Stein said. "The greatest curvature in the universe happens when two black holes merge.

"Astrophysicists want to use observations of black hole mergers to learn about the origins and history of black holes, and even if Einstein's equations need to be fixed. Our new tool allows scientists to model the outcome of a merger more accurately than previous models – at the same level of accuracy as simulations that take months of supercomputer time – but in a hundredth of a second."

Leo C. Stein

Campus Briefs

Donations Sought for 25th Annual Books and Bears Program

OXFORD, Miss. – The University of Mississippi is asking the community to help spread a little joy this holiday season by donating to the 25th annual Books and Bears program. Donations such as toys, books, dolls, bicycles and other children's play items are being accepted through Dec. 14. All donations will be collected and sorted

Read the story ...

More Posts from this Category

Thank You To Our Donors

Mississippi Excellence in Coaching Fellowship Aims to Build Leaders

OXFORD, Miss. – Twenty-five inaugural recipients of the Mississippi Excellence in Coaching Fellowship – a program hosted by the University of Mississippi School of Education in partnership with the Mississippi Association of Coaches and the Mississippi High School Activities Association – are expected to increase their impact on student-athletes and their communities. The coaching fellowship

Read the story ...

More Posts from this Category

Ole Miss In the News

Clarion-Ledger: New Essay Collection Tells the Story of Meredith's Enrollment

Essays celebrate 60th anniversary of James Meredith's enrollment at University of Mississippi By Lauren Rhoades Oct. 1 marks the 60th anniversary of James Meredith's 1962 enrollment at the University of Mississippi as the school's first African-American student.

For more on Stein's work and advice for aspiring physicists, check out **this Q&A with him**.

"We can predict what's left after a black hole merger – properties of the final black hole such as its spin and mass – with an accuracy 10 to 100 times better than what was possible before," said co-author Davide Gerosa, an Einstein Postdoctoral Fellow in Theoretical Astrophysics at Caltech. "This is important because tests of general relativity depend on how well we can predict the end states of black hole mergers."

The research is related to a larger effort to study black holes with the Laser Interferometer Gravitational-wave Observatory, known as LIGO, which made history in 2015 by making **the first direct detection of gravitational waves** emitted by a black hole merger. Since then, LIGO has detected **nine additional black hole mergers**.

Gravitational waves are ripples in space and time, first predicted by Einstein more than 100 years ago. Gravity itself, according to general relativity, is a warping of the fabric of space-time. When massive objects such as black holes accelerate through space-time, they generate gravitational waves.

One of the goals of LIGO and the thousands of scientists analyzing its data is to better understand the physics of black hole collisions and to use these data, in turn, to assess whether Einstein's general theory of relativity still holds true under these extreme conditions. A breakdown of the theory might open the door to new types of physics not yet imagined.

But creating models of colossal events such as black hole collisions has proven to be a daunting task. As the colliding black holes become very close to each another, just seconds before the final merger, their gravitational fields and velocities become extreme and the math becomes far too complex for standard analytical approaches.

"When it comes to modeling these sources, one can use the pen-and-paper approach to solve Einstein's equations during the early stages of the merger when the black holes are spiraling toward each other," Varma said. "However, these schemes break down near the merger. Simulations using the equations of general relativity are the only means to predict the outcome of the merger process accurately."

That is where supercomputers help out. The team took advantage of nearly 900 black hole merger simulations previously run by the **Simulating eXtreme Spacetimes** group using the Wheeler supercomputer at Caltech (supported by the Sherman Fairchild Foundation) and the Blue Waters supercomputer at the **National Center for Supercomputing Applications** at the **University of Illinois at Urbana-Champaign**.

The simulations took the equivalent of 20,000 hours of computing time. The Caltech scientists' new machine-learning program, or algorithm, learned from the simulations and helped create the final model.

"Now that we have built the new model, you don't need to take months," Varma said. "The new model can give you answers about the end state of mergers in milliseconds."

The researchers say that their model will be of particular importance in a few years, as LIGO and other next-generation gravitational-wave detectors become more and more precise in their measurements.

"Within the next few years or so, gravitational-wave detectors will have less noise," Gerosa said. "The current models of the final black hole properties won't be precise enough at that stage, and that's where our new model can really help out."

The Physical Review Letters study, titled **"High-accuracy mass, spin, and recoil predictions of generic black-hole merger remnants,"** was funded by the Sherman Fairchild Foundation, the National Science Foundation, NASA, the Brinson Foundation, and Caltech.

Authors include Stein, who earned his bachelor's degree at Caltech and is a former postdoctoral scholar

there; François Hébert, a postdoctoral scholar at Caltech; and Hao Zhang of the University of Pennsylvania and a former summer undergraduate research fellow at Caltech.

University of Mississippi Marketing and Communications contributed to this article

FILED UNDER: **COLLEGE OF LIBERAL ARTS**, **FEATURED NEWS**, **NEWS RELEASES**