Scientists spy on black-hole eating habits with 'LISA'

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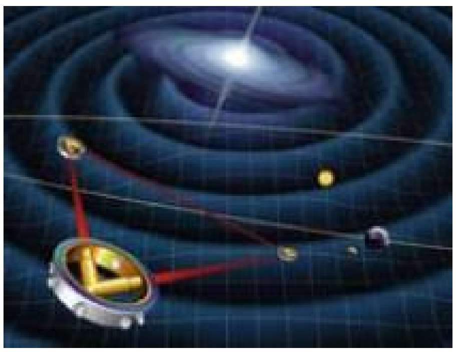

As big fish eat little fish in the Earth's vast oceans, so too do supermassive black holes gorge on smaller black holes and neutron stars, making themselves more massive in the process. Using sophisticated computer modeling, Penn State scientists have calculated the rate of this black-hole snacking, called "extreme-mass-ratio inspirals." They expect to see several events per year with the Laser Interferometer Space Antennae (LISA), a joint NASA-European Space Agency mission now in development.

Image: Artist's concept of the LISA mission. (NASA)

Steinn Sigurdsson, professor of astronomy and astrophysics at Penn State, discussed the inspiral rate during a presentation at the American

Astronomical Society meeting in San Diego. These events will be a major source of gravitational waves, which are ripples in spacetime. Sigurdsson said that this type of black hole inspiral provides one of the cleanest tests for assessing Einstein's theory of general relativity.

"Most galaxies contain a supermassive black hole, and from time to time a smaller black hole or neutron star will fall in," said Sigurdsson. "Very little light, if any, is emitted. This is done in the dark. Our best chance of studying the process is through gravitational radiation."

Predicted by Einstein, gravitational radiation has not yet been detected directly. These waves travel at light speed. Yet, unlike light waves, the subtle gravitational waves hardly interact with matter. A passing wave causes all matter to bob, like buoys on the ocean. LISA works by setting out three spacecraft -- buoys in spacetime -- and measuring the change in their separation as they bob in response to passing gravitational waves. The three LISA spacecraft will be separated from each other by over 3 million miles, while the gravitational waves alter the distance between them by far less than the width of an atom.

These waves, Sigurdsson said, grow more intense in the weeks just before the larger black hole consumes the smaller object. That is when LISA could detect an imminent merger. Higher-mass objects falling into the black hole might produce detectable waves years in advance of the merger. Sigurdsson puts the inspiral rate at about 1 per million years per galaxy. Because there are millions of galaxies in the visible universe, LISA might detect several inspirals each year.

Extreme-mass-ratio inspirals involve what scientists call compact objects -- stellar-size black holes, neutron stars, or white dwarfs. Supermassive black holes also can swallow stars like our sun. But these stars get ripped apart first, and they do not produce detectable gravitational waves.

Compact objects are dense. Neutron stars, for example, contain the densest material found in nature. As a result, they act like trace particles falling into a black hole, a perfect physics experiment. This is a clean merger without splintering. So, the mergers serve as very precise tests for Einstein's theory of general relativity. Any discrepancy between observation and theory would point to a flaw in general relativity.

LISA's lasers will measure tiny changes caused by passing waves in the motion of freely falling test masses in each spacecraft at a sub-nanometer accuracy. Technology to detect such subtle changes is now in development at several institutes, including Penn State. An ESA-led "LISA-Pathfinder" mission is expected to launch in 2008 to test formation flying and other technologies. LISA will launch a few years after this.

"The study of gravitational radiation is the newest frontier in astronomy," said Lee Samuel Finn, professor of astronomy and astrophysics and director of Penn State's Center for Gravitational Wave Physics. "Scientists and engineers around the world are working together to make LISA a reality. Steinn's work, one important piece among many, builds upon theories and models developed in recent years at Penn State and other institutes."

LISA will detect low-frequency waves, in the millihertz range. LIGO, the Laser Interferometer Gravitational Wave Observatory, will detect higher-frequency, kilohertz waves. The ground-based LIGO is funded by the National Science Foundation. Observations are being conducted at the two LIGO facilities, in Livingston, Louisiana, and Hanford, Washington.

LISA is a joint venture between NASA, the European Space Agency, and European national space agencies. In addition to leading the LISA Pathfinder mission, Europe will contribute much of the scientific instrumentation and the interplanetary propulsion systems to LISA. NASA's Goddard Space Flight Center will manage the mission for NASA and will provide the spacecraft and final integration. NASA's Jet Propulsion Laboratory will supply NASA's test package on LISA Pathfinder and the scientific instrumentation and operations support for the main LISA mission.

Source: Penn State