Scientists Generate Black Hole Radiation in the Lab

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Illustrations of photoionizing plasma systems. (Left) In a binary system consisting of a black hole and a companion star, X-rays are emitted from the accretion disk. (Right) In the photoionized plasma experiment, a hollow plastic shell is imploded with 12 laser beams, creating a plasma that produces X-rays similar to those near a black hole. Image credit: Hubble European Space Agency.

(PhysOrg.com) -- Due to their violent nature and long distance from Earth, black holes and their surroundings are very difficult to study. Currently, the main method to observe a black hole is to use an X-ray satellite to detect the X-ray fluorescence emitted by a black hole's companion star as the star's material falls into the black hole. But now, scientists have developed a laser-driven method to generate a flash of brilliant Planckian X-rays in the lab that can be used to simulate the X-rays that exist near black holes. The new results contrast with the generally accepted explanation for the origins of these astronomical features, and may also help scientists test the complex computer codes used in X-ray astronomy.

The team of researchers, Shinsuke Fujioka, et al., from Osaka University, the Chinese Academy of Sciences, the Korea Atomic Energy Research Institute, and Shanghai Jiao Tong University, have published their study on creating Planckian X-rays in the laboratory in a recent issue of Nature Physics.

In their study, the researchers used a direct laser-driven implosion to create a hot, dense plasma. They aimed 12 intense laser beams (for a total of 3 billion watts, and carrying 4.0 kJ [kilojoules] of energy) onto a micrometer-sized spherical hollow plastic shell. When the shell's core imploded, its temperature approached 1 keV (kiloelectronvolt), creating a hot plasma. With other adjustments to the set-up, the researchers could produce a slowly expanding, cool plasma, much like the astronomical plasma observed near black holes. In the laboratory-generated plasma, the researchers detected the emitted X-rays and measured their spectra.

They identified two characteristic spectral peaks that closely resemble the spectral peaks observed in the binary systems Cygnus X-3 and Vela X-1. In the model of Cygnus X-3, which consists of a black hole and a companion star, the gravitational energy of the star's accreting material is converted into thermal energy, which is the origin of the radiation emitted by the accretion disk. The X-ray spectra of Cygnus X-3 was previously observed by an X-ray spectrometer onboard the Chandra X-ray satellite.

"Astronomers use computer simulation codes to interpret their observational data, e.g. x-ray spectra and x-ray images," Fujioka told PhysOrg.com. "Because matter near a black hole is in extreme conditions (very hot and very massive), which was difficult to be reproduced on the Earth, astronomers could not validate their simulation results with valid experimental data; namely, astronomers were not sure whether their simulation results and their interpretations were correct or not.

"Furthermore, astronomers cannot directly measure temperature, density, and pressure of astronomical objects; there are many unknown parameters to interpret their observations. On the other hand, we can easily measure them in the laboratory. Our experimental technique offers astronomers a test bed to validate their models and simulations by comparing them to the experimental results obtained under well-characterized extreme conditions."

Although the X-ray spectra obtained in the lab resemble those observed astronomically, their interpretations are very different, and even contradictory. Most significantly, the first spectral peak in the two binary systems is thought to be a forbidden resonance line of helium-like silicon ions. However, as Fujioka explained, these differences could help astronomers test the computer codes used in X-ray astronomy modeling.

"X-ray spectroscopy of photoionized plasma near a black hole is an important tool to study the evolution of a black hole," Fujioka said. "Astronomers can reproduce their observational data even with incorrect or wrong models owing to adjusting the unknown parameters. If their codes are not valid, characteristics (temperature, density, mass, pressure etc.) of the binary systems may be changed. We hope that our result improves their understanding of the birth, growth, and death of a black hole."

More information: Shinsuke Fujioka, et al. "X-ray astronomy in the laboratory with a miniature compact object produced by laser-driven implosion." *Nature Physics*, Vol. 5, November 2009. Doi:10.1038/NPHYS1402