Astronomers use supercomputers to study atoms linked to black holes

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Super-hot atoms in space hold the key to an astronomical mystery, and an Ohio State University astronomer is leading an effort to study those atoms here on Earth.

Anil Pradhan, professor of astronomy, and his team have used supercomputers to perform the most precise energy calculations ever made for these atoms and their properties. As a result, astronomers -- in particular, those hunting black holes -- will have a better idea of what they are looking at when they examine faraway space matter using X-ray telescopes.

The results appear in the September issue of the *Journal of Physics B: Atomic, Molecular and Optical Physics*. And while the paper's subject matter is highly technical, it tells a story that weaves together atomic physics, Einstein's theory of relativity, cutting-edge astronomical observations, and some of the world's fastest supercomputers.

Astronomers have spied seas of super-hot atoms in plasma form, circling the centers of very bright galaxies, called active galactic nuclei. The plasma is thought to be a telltale sign of a black hole; the black hole itself is invisible, but any material spiraling into it should be very hot, and shine brightly with X-rays.

Before anyone can prove definitively whether active galaxies contain black holes, astronomers need to measure the energy levels of the excited atoms in the plasma very precisely, and match the measurements with what they know about atomic physics.

Assuring the accuracy of atomic data doesn't sound like the most exciting job in astronomy, Pradhan admitted -- but it is fundamentally important.

"Most astronomers take it for granted that the atomic data they are referencing are correct -- they have to, in order to interpret their observations," he said.

For 30 years, the professor of astronomy has worked on the problem. The new, high-resolution X-ray data gathered by NASA's Chandra X-ray Observatory and the European Space Agency's X-ray Multi-mirror Mission-Newton satellite spurred him on. Believing that such high-quality observations demanded good atomic data, he and his team -- which is also led by Ohio State senior research scientist Sultana Nahar -- decided to make the most precise atomic calculations possible.

After years of writing computer codes and thousands of hours of computing time at the Ohio Supercomputer Center, they calculated the energy levels of high-temperature atoms ranging from carbon to iron -- the atoms found in these plasmas.

Some of the previously accepted values for these atoms had acknowledged error rates from 30 percent to as high as factors of two or three. With the new calculations reported in this study, the error for all the atoms has been reduced to a few percent.

This means that from now on, when astronomers record X-ray images of objects in space, they will have a much better idea of what atoms make up the material they are looking at, and the physical conditions inside that object.

The atom that most black-hole hunters are interested in is iron, and that's where Einstein's general theory of relativity comes in.

The immense gravity of a black hole should, according to relativity, distort the X-ray signal as seen from Earth, particularly for iron atoms. The signal is a spectrum, and looks like a series of lines, with each atom having its own line. One line in particular, called the iron K-alpha line, appears broadened for X-rays emanating from the center of active galaxies, and it is often cited as a key indication of a black hole.

Thirteen years ago, Pradhan, Nahar, and their colleagues began a study called the Iron Project. Their goal, in part, is to find out why the iron K-alpha line is broadened and what the implications are for X-ray astronomy.

"The most direct observation of a black hole is considered to be the iron K-alpha line," Pradhan said. "So it's very important to find out whether it's been broadened because there is a black hole nearby, or if there is some other cause."

He is hopeful that astronomers will apply his new data to studies of the iron K-alpha line and help solve the mystery.

Source: Ohio State University