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[Editor's note: the presentation "*Auger Electrons via K-Alpha X-Ray Lines of Platinum Compounds for Nanotechnological Applications*" will take place Friday, June 24, 2011 at 8:30 a.m. ET in Rm. 170 of the math annex at Ohio State University.]

ASTRONOMERS REACH FOR THE STARS TO DISCOVER NEW CANCER THERAPY

COLUMBUS, Ohio – Astronomers' research on celestial bodies may have an impact on the human body.

Ohio State University astronomers are working with medical physicists and radiation oncologists to develop a potential new radiation treatment – one that is intended to be tougher on tumors, but gentler on healthy tissue.

In studying how chemical elements emit and absorb radiation inside stars and around black holes, the astronomers discovered that heavy metals such as iron emit low-energy electrons when exposed to X-rays at specific energies.

Their discovery raises the possibility that implants made from certain heavy elements could enable doctors to obliterate tumors with low-energy electrons, while exposing healthy tissue to much less radiation than is possible today. Similar implants could enhance medical diagnostic imaging.

Friday, June 24, at the International Symposium on Molecular Spectroscopy, Ohio State University senior research scientist Sultana Nahar will announce the team's computer simulations of the elements gold and platinum, and the design of a prototype device that generates X-rays at key frequencies.

Their simulations suggest that hitting a single gold or platinum atom with a small dose of X-rays at a narrow range of frequencies – equal to roughly one tenth of the broad spectrum of X-ray radiation frequencies – produces a flood of more than 20 low-energy electrons.

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"From a basic physics point of view, the use of radiation in medicine is highly indiscriminate," Pradhan added. "Really, there has been no fundamental advance in X-ray production since the 1890s, when Roentgen invented the X-ray tube, which produces X-rays over a very wide range." No fundamental advance, that is, until now.

"As astronomers, we apply basic physics and chemistry to understand what's happening in stars. We're very excited to apply the same knowledge to potentially treat cancer," Nahar said.

"We believe that nanoparticles embedded in tumors can absorb X-rays efficiently at particular frequencies, resulting in electron ejections that can kill malignant cells," she continued. "From X-ray spectroscopy, we can predict those energies and which atoms or molecules are likely to be most effective."

Nahar and Anil Pradhan, professor of astronomy at

Ohio State, discovered that particular frequencies of X-rays cause the electrons in heavy metal atoms to vibrate and break free from their orbits around the nucleus, creating what amounts to an electrically charged gas, or plasma, around the atoms at the nanometer scale.

They have thus dubbed their medical concept Resonant Nano-Plasma Theranostics (RNPT) – the latter word a merger of “therapy” and “diagnostics.”

“From a basic physics point of view, the use of radiation in medicine is highly indiscriminate,” Pradhan added. “Really, there has been no fundamental advance in X-ray production since the 1890s, when Roentgen invented the X-ray tube, which produces X-rays over a very wide range.”

No fundamental advance, that is, until now.

“Together with long-time collaborator and medical physicist Yan Yu from Thomas Jefferson University Medical College, we’ve developed the RNPT methodology, which we hope will have far-reaching consequences for X-ray imaging and radiation therapy,” Pradhan said.

He explained why metals such as gold or platinum display this behavior, and how hospitals can take advantage of it. The basic physics, he said, has been well understood since the 1920s.

Physicists have long known that electrons orbit the nuclei of atoms at different distances, some close to the nucleus and some farther away. When one of the close-in electrons is lost, a far-out electron may drop in to take its place, which releases energy. This is called the Auger effect, which was discovered in 1922.

Often the energy is strong enough to kick out a second electron, called an Auger electron. The same process could also result in the emission of light particles, or photons, at specific energies or frequencies, the most prominent of which are called

K-alpha X-rays.

The astronomers believe that K-alpha X-ray frequencies kick the close-in electrons out of heavy metal atoms such as platinum, causing many far-out electrons to fall in, and many more electrons to be kicked out. These free Auger electrons are low in energy but great in number, and could feasibly bombard nearby malignant cells and shatter their DNA.

While typical therapeutic X-ray machines such as CT scanners generate full-spectrum X-rays, hospitals could employ RNPT using only K-alpha X-rays, which would greatly reduce a patient's radiation exposure.

That's the function of the proof-of-principle device that the team has constructed. Though the working tabletop prototype needs to be further developed, these first experiments show that the Auger effect can be used to deliver specific frequencies of X-ray radiation to heavy metal nanoparticles embedded in diseased tissue for imaging or therapy.

Gold and Platinum are only the first two elements that the team is studying in detail for the application of the RNPT methodology. Both metals are safe to use in the body. Platinum is already used in the chemotherapy drug cisplatin, where it helps deliver the drug by binding to malignant DNA.

"This work could eventually lead to a combination of radiation therapy with chemotherapy using platinum as the active agent," Pradhan said.

Cancer therapy is new territory for the astronomers. Together with Yu, they came upon the idea for RNPT when they were trying to understand the abundance of different chemical elements inside stars.

Their goal at the time was to help astronomers understand what different stars are made of, based on how radiation flows through them and emanates from them.

Astronomers already have several methods for doing this, but their results vary widely. By simulating how different elements behave when exposed to the radiation inside stars, Nahar and Pradhan hope to help astronomers determine precisely what our sun is made of.

Even for a profession as mathematically rigorous as astronomy, Nahar and Pradhan's undertaking is staggeringly large. They must calculate how every possible atom contained in a star will react to every possible wavelength of energy. They rely on the Ohio Supercomputer Center for these calculations and simulations; in fact, their research team has ranked among the biggest users of computational resources ever since the center's establishment more than two decades ago.

The simulations have started to pay off, in an astrophysical sense. They have revealed that previous observations and calculations of chemical abundances of the sun may in fact be off by as much as 50 percent.

Even more surprising to the astronomers were the results for simulating the radiation absorption by heavy metal atoms, such as iron. Iron plays the dominant role in controlling radiation flow through stars, but it is also observed in some black hole environments, where K-alpha X-rays can be detected from Earth.

"That's when we realized that the implications went way beyond atomic astrophysics," Pradhan said. "X-rays are used all the time in radiation treatments and imaging, and so are heavy metals – just not in this way. If we could target heavy metal nanoparticles to certain sites in the body, X-ray imaging and therapy could be more powerful, reduce radiation exposure, and be much more precise."

Leading a multi-disciplinary team, Nahar, Pradhan, and Yu are working with several colleagues in the departments of radiation oncology at Ohio State and Thomas Jefferson University Medical College to further explore these medical applications.

The Ohio State collaborators include Russell Pitzer, professor emeritus of chemistry, Enam Chowdhury, senior research associate in physics, and Sara Lim, a graduate student in biophysics. They also worked with Kaile Li and Jian Wang, assistant professors in radiation oncology; former postdoctoral researchers Max Montenegro (now of the Pontificia Universidad Católica de Chile), and Chiranjib Sur (now of the high-performance computing group of IBM's India Software Lab); and graduate student Mike Mrozik in chemical physics.

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