Q&A: Cosmic rays, space weather and larger questions about the universe

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GSU
Cosmic Muon
Telescope
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The new technology developed by Georgia State researchers is used for studying both space and terrestrial weather. Credit: Courtesy: Georgia State University

With the naked eye, you can't see the weather in space, or feel the cosmic rays beaming down to Earth—but they can impact critical systems like our climate, computer connectivity, communications and even our health.

Regents' Professor of Physics and Astronomy Xiaochun He is taking on some of the big questions by making measurement of these cosmic rays using the technologies developed in his fundamental nuclear physics research projects. He and his team are gauging how these rays are affecting earth's climate, how they may have played a role in the origins of the universe and how they may play a role when cancer originates in the body.

Here, Dr. He shares what inspired this work and how studying cosmic rays can make an impact here on Earth.

What is space weather, and why do we need to monitor it?

Space weather is a general term for describing solar activities, including coronal mass ejection from the sun and things like geomagnetic storms. Severe solar storms could cause significant interruptions to our communication system, potentially damage satellites, and affect the long-distance power grid, for example.

Are cosmic rays different from space weather?

Most of the energetic cosmic ray particles—mainly protons—have a galactic origin; some of them enter the solar system and bombard the Earth's atmosphere. These cosmic ray particles collide with the molecules in the Earth's atmosphere around 15 kilometers in altitude and produce secondary particles (called cosmic ray showers).

The most secondary particles that reach the surface of the earth are muon particles, which are detected by our detectors. Space weather does influence the amount of cosmic ray particles entering the Earth's atmosphere, which is why we can use the data from our detectors to study the changes in space weather.

Your team has developed cosmic ray detectors to gather critical measurements, including space and earth weather monitoring. What is the goal of this work?

The cosmic ray muon detectors were developed by me and my students in the Nuclear Physics Group at Georgia State.

As of today, we have installed two detectors in Sri Lanka, one in Singapore, and one in Colombia, outside of the U.S. We also have detectors installed at the CHARA Array on Mount Wilson, Calif., and at Apache Point Observatory in New Mexico.

The current plan is to install two more detectors in Africa and one in Serbia before the end of this summer. My longer-term goal is to install at least one detector in every country in the world, hopefully, before I retire from Georgia State.

What makes these detectors unique and important?

The key features of our detector include portability, low-cost, easy installation and data collection. Given the fact that the cost of the detector is cheaper than the cost of an iPhone, it is practically possible to deploy these detectors to many locations worldwide.

How do these detectors help to gather data about how our climate is changing?

The climate warming causes the expansion of the atmosphere to higher altitude and extreme weather events worldwide. These changes influence the amount of cosmic ray particles recorded by our detectors.

By analyzing the data, we hope to develop a robust model for monitoring the extreme weather patterns and the changes in climate on Earth. It will take years to achieve this goal. Currently, our students are actively developing machine learning tools for analyzing the existing data. The progress will evolve as more detectors come online.

Part of your work includes a project that will design detectors for a micro-satellite NASA mission. Tell us more about this work.

Both the space and the Earth's weather will influence the particle counts recorded by our detectors. In many cases, it is a challenge to separate these effects. One of the ideas is to put a smaller detector at the low Earth orbit for tagging the space weather events.

Last year, Dr. Ashwin Ashok and I visited the NASA Ames Research Center and developed a prototype following NASA's CubeSat specifications. According to our friends at NASA, we hope the prototype can be launched into space in 2025.

Beyond the impact cosmic rays can have on the atmosphere, you think they may even play a role in human health. Can you share some of the work you are interested in?

Cosmic rays existed long before life was created on Earth, which is a part of the natural background radiation that human beings experience. I think ionizing radiation is likely linked to some cancer formation, and I would like to see more research in this area. Since cosmic rays are ionizing radiation that can cause gene mutation and double-strand DNA breaking, it is important to understand the role of cosmic rays in the evolution of life on Earth, which is important for space travel.

In addition, since the cosmic ray showers are typically occurring a few kilometers above the flight altitude of commercial flights, more radiation dosages are being received by flight crews. For many years, I carried a Geiger counter with me when I was traveling and recorded the increase of cosmic ray radiation levels between 20 to 40 times higher in comparison to the levels on the ground.

I have long been interested in understanding the health effects of these increased levels of radiation. Over the past two years, I was able to use our own detector to have a much better measurement of the cosmic ray radiation increase with significant statistical accuracy.

You also think these detectors could help inspire middle and high school students to learn more about STEM research. Can you share more about that?

In addition to my research, teaching courses and working with a team of talented graduate students are some of the most rewarding aspects of my work. Following the formation of the Cosmic RISE Team with our interdisciplinary faculty, we see a great opportunity to use the newly developed detector for STEM training.

The detector cost is manageable, and the devices are both portable and easy to operate. At the same time, these detectors make it possible to encourage STEM education for students across cultural differences and language barriers for students, especially those in developing countries.

Along with your cosmic ray detection work, you also conduct research at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory. How does this all connect?

My main research project, as a high-energy nuclear physicist, is to collide gold nuclei near the speed of light using the Relativistic Heavy Ion Collider at Brookhaven National Lab, which has been supported by the U.S. Department of Energy since 1998. I am grateful to have been able to assemble a world-class team of nuclear physicists at Georgia State, including Murad Sarsour, Megan Connors, and Dr. Yang-Ting Chien.

The idea is that the matter state created from the colliding nuclei is so hot and dense and is very similar to the matter state a few microseconds after the Big Bang. Through these experiments, we will gain more knowledge about the evolution of the early universe, which in turn allows us to have a better understanding of the formation of stars and galaxies when the universe cools and continues expanding. At some point, in the presence of cosmic ray radiations, life is created.

Over the years, I was able to use the technologies from this project and develop cosmic ray detectors for practical applications for solving the most pressing concern in the world—climate warming.

Provided by Georgia State University

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