Physicists and astronaut discuss cosmic ray detector's findings of possible signs of dark matter

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Astronaut Michael Fincke '89 captured this image of his own reflection during a spacewalk. The AMS, already installed on the International Space Station, is just behind him at top left. Credit: NASA

Two MIT physicists and an alumnus who's a NASA astronaut spoke on campus earlier this week, describing an experiment that's been 18 years in the making and yielded its first significant results just last week.

The experiment, called the Alpha Magnetic Spectrometer, or AMS, was mounted on the side of the orbiting International Space Station (ISS) in May 2011, when it was delivered there by a space shuttle crew that included astronaut Michael Fincke '89. Fincke has logged more time in space than any other active astronaut, having spent more than a year in space, including more than 50 hours on spacewalks.

Fincke and Andrei Kounine, a senior researcher in MIT's Laboratory for Nuclear Science and AMS's coordinator for physics analysis, described the experiment's results, and the process of getting the experiment into space. They were introduced by Samuel Ting, the Thomas D. Cabot Professor of Physics, who conceived of the AMS experiment 18 years ago and led its development and deployment. The $1.6 billion project ultimately involved 650 scientists from more than 50 universities and agencies in 16 countries.

So far, the magnetic detector has recorded more than 30 billion "events"—impacts from cosmic rays. Of those, 6.8 billion have been identified as impacts from electrons or their antimatter counterpart, positrons—identified through comparisons of their numbers, energies and directions of origin.

AMS's most eagerly anticipated findings—observations that would either confirm or disprove the existence of theoretical particles that might be a component of dark matter—have yet to be made, but Ting expressed confidence that an answer to that question will be obtained once more data is collected. The experiment is designed to keep going for at least 10 years.

In the meantime, the results so far—showing more positrons than expected—already demonstrate that new physical phenomena are being observed, Ting and Kounine said. What's not yet clear is whether this is proof of dark matter in the form of exotic particles called neutralinos, which have been theorized but never observed, or whether it can instead be explained by emissions from distant pulsars.

Kounine explained that in addition to its primary focus on identifying signs of dark matter, AMS is also capable of detecting a wide variety of phenomena involving particles in space. For example, he said, "it can identify all the species of ions that exist in space"—particles whose abundance may help to refine theories about the origins and interactions of matter in the universe. "It has great potential to produce a lot more physics results," Kounine said.

An answer on whether the observed particles are being produced by collisions of dark matter will come from graphing the numbers of electrons and positrons versus the energy of those particles. If the number of particles declines gradually toward higher energies, that would indicate their source is probably pulsars. But if it declines abruptly, that would be clear evidence of dark matter.

"Clearly, these observations point to the existence of a new physical phenomenon," Kounine said. "But we can't tell [yet] whether it's from a particle origin, or astrophysical."

Fincke, one of two astronauts who actually attached the AMS to the exterior of the ISS, said he was honored to have had the opportunity to deliver such an important payload. He was joined on the mission—the last flight of space shuttle Endeavour, and the second-to-last of NASA's entire shuttle program—by another MIT alum, Greg Chamitoff PhD '92.

Before the mission, the Endeavour astronauts visited CERN in Switzerland, where AMS's mission control center is located, to learn about the precious payload they would be installing, Fincke said. "That got our crew to be extremely motivated to ensure success," he said.

The device itself, Fincke explained, "was built to have as little interaction with astronauts as possible": Once bolted into place, it requires no further attention. And while it was designed to withstand inadvertent impacts, he said that he and his fellow astronauts were careful to give it a wide berth. "We didn't want to even get close," he said.

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