In Search of Antimatter Galaxies

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The Alpha Magnetic Spectrometer. Image courtesy MIT.

NASA's space shuttle program is winding down. With only about half a dozen more flights, shuttle crews will put the finishing touches on the International Space Station (ISS), bringing to an end twelve years of unprecedented orbital construction. The icon and workhorse of the American space program will have finished its Great Task.

But, as Apple's CEO Steve Jobs might say, there is *one more thing*...

An act of Congress in 2008 added another flight to the schedule near the end of the program. Currently scheduled for 2010, this extra flight of the shuttle is going to launch a hunt for antimatter galaxies.

The device that does the actual hunting is called the Alpha Magnetic Spectrometer--or AMS for short. It's a $1.5 billion cosmic ray detector that the shuttle will deliver to the ISS.

In addition to sensing distant galaxies made entirely of antimatter, the AMS will also test leading theories of dark matter, an invisible and mysterious substance that comprises 83 percent of the matter in the universe. And it will search for strangelets, a theoretical form of matter that's ultra-massive because it contains so-called strange quarks. Better understanding of strangelets will help scientists to study microquasars and tiny, primordial black holes as they evaporate, thus proving whether these small black holes even exist.

All of these exotic phenomena can make their presence known by the ultra-high energy cosmic rays they emit--the type of particles AMS excels in detecting.

"For the first time, AMS will measure very high-energy cosmic rays very accurately," explains Nobel laureate Samuel Ting, a physicist at the Massachusetts Institute of Technology, who conceived of the AMS and has guided its development since 1995.

An aerial view of CERN, the European Organization for Nuclear Research. The Alpha Magnetic Spectrometer is a sort of "mini-CERN" in space. Image credit: CERN

Antimatter galaxies, dark matter, strangelets--these are just the phenomena that scientists already know about. If history is any guide, the most exciting discoveries will be things that nobody has ever imagined. Just as radio telescopes and infrared telescopes once revealed cosmic phenomena that had been invisible to traditional optical telescopes, AMS will open up another facet of the cosmos for exploration.

"We will be exploring whole new territories," Ting says. "The possibility for discovery is off the charts."

Ting often compares AMS with high-powered particle accelerators at facilities such as CERN in Geneva, Switzerland. Rather than detecting high-speed cosmic rays from across the galaxy, these underground accelerators make their own particles locally using tremendous amounts of electrical power. To study the particles, CERN and AMS employ the same basic trick: Both use strong magnetic fields to deflect the particles, and arrays of silicon plates and other sensors inside the detectors track the particles' curved paths.

Many terabytes of data pour out of these sensors, and supercomputers crunch that data to infer each particle's mass, energy, and electric charge. The supercomputer is part of why AMS must be mounted onto the ISS rather than being a free-flying satellite. AMS produces far too much data to beam down to Earth, so it must carry an onboard supercomputer with 650 CPUs to do the number crunching in orbit. Partly because of this giant computer, AMS requires 2.5 kilowatts of power — far more than a normal satellite's solar panels can provide, but well within the space station's 100 kilowatt power supply.

"AMS is basically an all-purpose particle detector moved into space," Ting says.

There are two important differences between AMS and underground accelerators, though. First, AMS will detect particles such as heavy nuclei that have vastly higher energies than particle accelerators can muster. The most powerful particle accelerator in the world, the Large Hadron Collider at CERN, can collide particles with a combined energy of about 7 tera-electronvolts (TeV, a common way to measure energy in particle physics). In contrast, cosmic rays can have energies of 100 million TeV or more. The other important difference is that accelerators smash particles into each other to learn about the particles themselves, while AMS will sample high-energy particles from deep space for the sake of learning more about the cosmos.

For example, a longstanding mystery in cosmology is the case of the missing antimatter. According to physicists' best models, the Big Bang should have produced just as much antimatter as matter. So, where did all the antimatter go? It can't be nearby, because if it were, we would see bright X-ray emissions where the antimatter came into contact with matter and annihilated.

An artist's concept of the Alpha Magnetic Spectrometer installed on the International Space Station.

One explanation could be that some distant galaxies are made entirely of antimatter instead of matter. Since antimatter doesn't look any different than ordinary matter, astronomers would not be able to tell whether a distant galaxy is made of matter or antimatter just by looking at it. However, AMS would find strong evidence of antimatter galaxies if it detected even a single nucleus of anti-helium or a heavier antimatter element.

Collisions among cosmic rays near Earth can produce antimatter particles, but the odds of these collisions producing an intact anti-helium nucleus are so vanishingly small that finding even one anti-helium nucleus would strongly suggest that the nucleus had drifted to Earth from a distant region of the universe dominated by antimatter.

Other instruments such as the Italian PAMELA satellite have looked for anti-helium nuclei, but none have been sensitive enough to rule out the existence of antimatter galaxies. AMS has about 200 times the particle-collecting power of anything that has flown before. If AMS detects no anti-helium nuclei, Ting says scientists will know that there are no antimatter galaxies within about 1000 megaparsecs — or roughly to the edge of the observable universe.

Another mystery that AMS will help solve is the nature of dark matter. Scientists know that the vast majority of the universe is actually made of unseen dark matter rather than ordinary matter. They just don't know what dark matter is. A leading theory is that dark matter is made of a particle called the neutralino. Collisions between neutralinos should produce a large number of high-energy positrons, so AMS could prove whether dark matter is made of neutralinos by looking for this excess of energetic positrons.

"For the first time we could find out what dark matter is made of," Ting says.

Source: by Patrick Barry, Science@NASA