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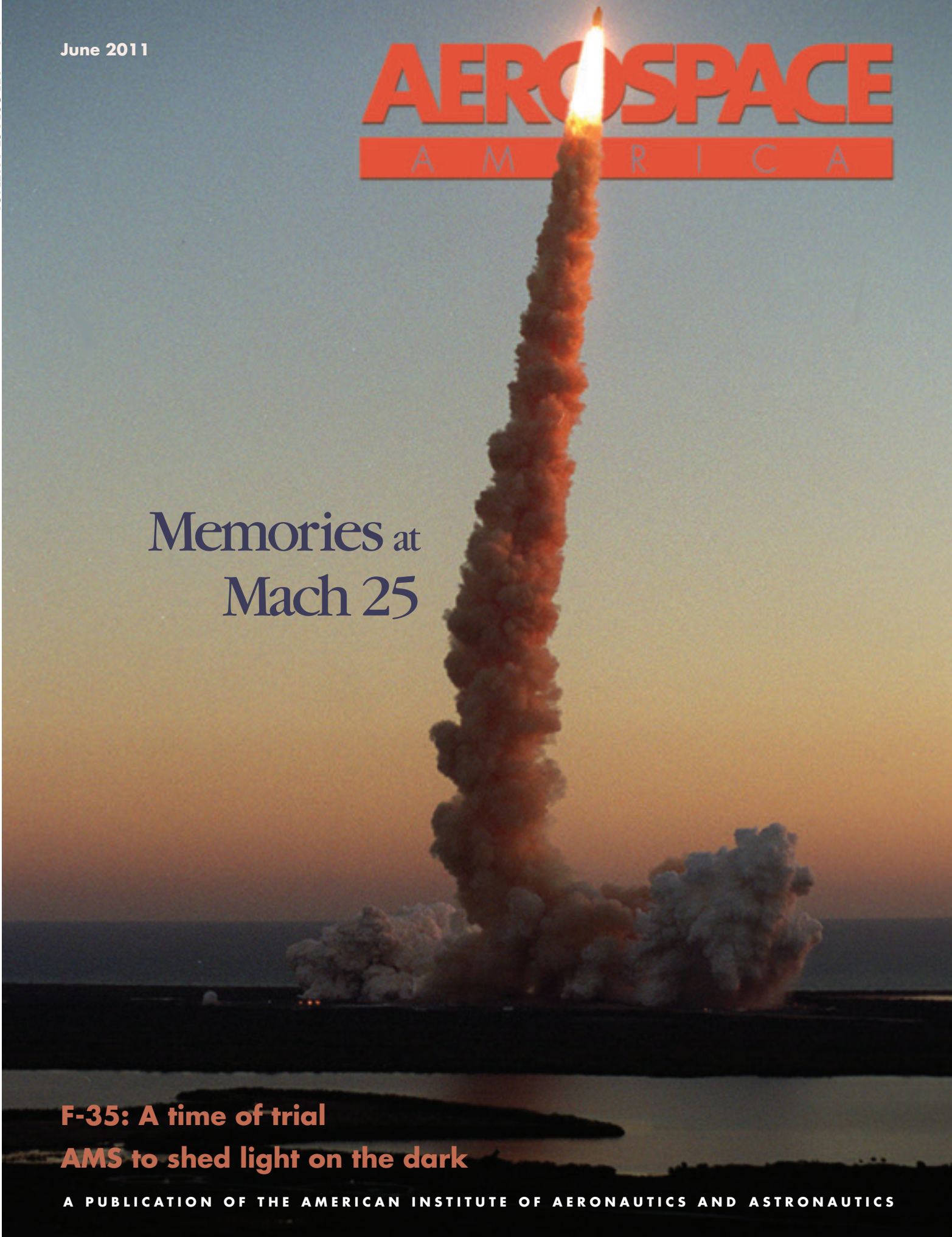

Memories at Mach 25

F-35: A time of trial

AMS to shed light on the dark

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The AMS is positioned in the aft payload bay of Endeavour. Note the manipulator arm at the left of AMS and the bright silver lining of the partially open payload bay doors. The crew cabin is at the opposite end of the payload bay. ©Michele Famiglietti.

AMS: Shedding light on the dark

by Craig Covault
Contributing writer

The Alpha Magnetic Spectrometer (AMS), the largest scientific instrument on the ISS, will conduct an unprecedented search for previously undetectable antimatter and for invisible dark matter, which (along with dark energy) makes up 95% of the universe, theorists believe. Astronauts were to deliver the instrument and attached it to the left end of the space station's 300-ft truss during STS-134, the last flight of the shuttle Endeavour and the penultimate mission of the 30-year space shuttle program.

The AMS high-energy particle detector will be gathering evidence concerning two of the greatest mysteries of the universe: What caused the disappearance of primordial antimatter, which was formed in equal amounts with the visible matter that makes up the current universe; and just what is this stuff called dark matter, which neither reflects nor emits light, yet bends light from other sources, and exerts such a powerful gravitational force that it has shaped galaxies and formed them into giant linked structures up to 10 billion light-years across?

Bone of contention

But while the AMS science team probes momentous issues governing the universe, political controversy in Congress and elsewhere could arise over the 4,000 lb of Chinese hardware that has finally made its way onto the ISS as a critical element of the station's most historic instrument. This has occurred in spite of NASA, White House, and congressional opposition to Chinese participation in the ISS program.

The 15,000-lb AMS is a Dept. of Energy project, and most of its $1.5-billion cost has been borne by multiple European and Asian participants, including China.

The two tons of Chinese components include 4,000 permanent magnets. These comprise the inner walls of the barrel-shaped instrument through which AMS scientists hope to track cosmic particles from the Big Bang so that detectors can measure their properties. The researchers hope that finding key particles and atoms will prove the existence of dark matter, dark energy, and antimatter.

The AMS-02, loaded with 2 tons of Chinese magnets, undergoes final processing at the Kennedy Space Center before its launch to the ISS.

The Chinese magnets are important from a U.S. policy standpoint. These magnets and support hardware were retrofitted in place of a canceled multimillion-dollar U.S./European cryogenically cooled electromagnetic system that AMS project leaders determined would not perform as well as hoped. The heating needed to run the electromagnets was greater than expected and would consume roughly double the planned amount of liquid helium, reducing useful life to less than two years. Thus the cryogenic system in the works for 10 years was removed and replaced with the permanent magnets, which can keep the AMS functional through the remaining 20-30-year life of the station.

Now mounted on the ISS, the Alpha Magnetic Spectrometer will probe cosmic mysteries, seeking evidence that dark matter, dark energy, and antimatter do exist. Such a discovery could explain what occupies most of the known universe. However, political controversy involving China's participation in the effort could cast a shadow over this exciting prospect.

The retrofit of this unique space instrument with such a large amount of Chinese equipment comes face-to-face with strong debate—and some outright hostility—in congressional and policy circles about whether the U.S. should engage in space cooperation with the Chinese, given their internal human rights record and a surging military space program aimed at countering the U.S. There had been congressional

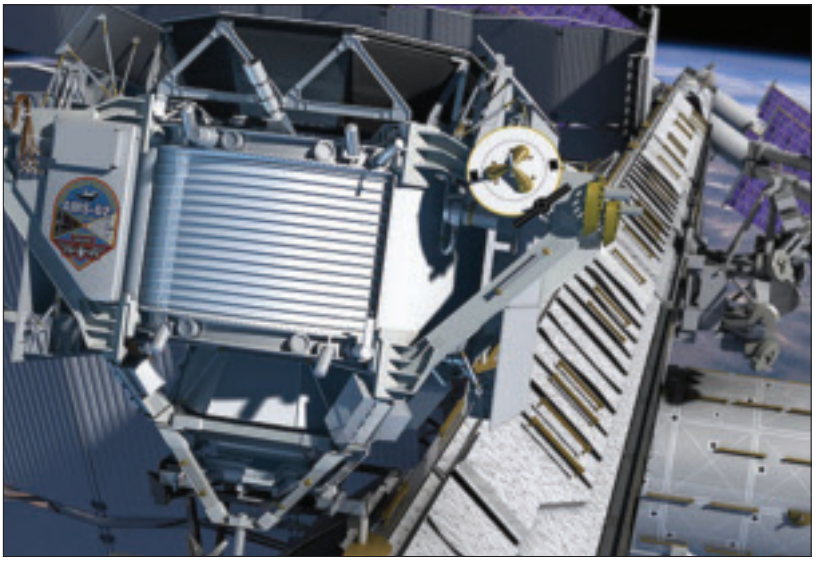
After delivery to the station, the AMS will sit atop the far left truss.

oversight and, in 2008, approval to fund delays. However, this came before the decision to replace the cryogenic system with magnets that had been used for a short proof-of-concept flight on STS-91 in 1998.

AMS-02, as large as an automobile, is to be attached to the exterior of the station's port truss—a large instrument in a prominent place. That is ironic, because for more than 10 years NASA has rejected all Chinese overtures seeking involvement with the space program in general and the space station specifically.

The head of the Chinese National Space Administration (CNSA) even used this author, during one of six trips to Beijing, as an intermediary between himself and then-NASA Administrator Dan Goldin in an attempt to open talks on Chinese participation in the station effort. "Without China's participation, the ISS is not a true international program," said CNSA Administrator Luan Enjie. Goldin rejected the Chinese overture, as has every administrator and administration since. But now, with AMS-02's thousands of pounds of critical Chinese components, China's technology has made it onto the station as a key aspect of ISS science operations.

The AMS will wait for signs of antimatter and dark matter to pass through it for the next 20-30 years of ISS operations.



Breakthroughs in detection

The 7.5-ton instrument could detect direct evidence of the dark matter that scientists believe forms the framework of the universe, holding galaxies together, forming them into groups, and then linking those groups into mammoth cosmic structures, including one that spans 10 billion light-years. Once analyzed at the cosmic particle level, dark matter could also help to prove whether antimatter indeed makes up entire galaxies that could be part of an unseen parallel universe, and whether that antimatter could annihilate everything in the known cosmos.

The key technological theories and components making dark matter and antimatter detection possible result from Chinese breakthroughs, according to Samuel C.C. Ting, a 1976 Nobel Prize-winning scientist at MIT, where one AMS Payload Operations Control Center will be based. Ting has spent most of the past 20 years building a coalition of 500 scientists from 60 institutions in 16 countries, to develop, build, and test AMS-02. All the international agreements involving the instrument are the responsibility of DOE, says NASA. However, the DOE connection may not make much difference to members of Congress.

The key to solving the performance issue that brought about the need for China's technology is that the Chinese magnets use a neodymium, iron, and boron alloy from Germany. Says Trent Martin, AMS project manager at NASA Johnson, the Chinese took this raw, unmagnetized material to shape, magnetize, and fit into the instrument's structure. "The latest development of the Chinese technologies for making permanent magnets has made AMS experiment possible," said Ting in a letter to DOE.

Assembly and testing of the Chinese hardware have taken place at some of the most important defense plants in China, including the Institute of Electrical Engineering and the Chinese Academy of Launch Vehicle Technology in Beijing. Lockheed Martin engineers traveled to these Chinese plants to ensure components were assem-

bled precisely and safely—the magnetic force between adjoining blocks is 4 tons.

Difficult timing

Sharp restrictions against any NASA relationship with China were levied just as the AMS-02 instrument has been in final development. NASA tries to avoid any controversy by noting that the international aspects of AMS are managed by DOE.

But the agency's new FY11 budget just signed by the president precludes cooperation with China. The bill specifically bans NASA and the White House Office of Science and Technology Policy from spending any funds to discuss or arrange space cooperation with China unless specifically authorized to do so by Congress.

In June 1998 a prototype version of the instrument, AMS-01, including the same 2 tons of Chinese components flew for 10 days as an attached payload on board the orbiter Discovery's STS-91 mission. But it carried more than a test version of the instrument. With NASA and DOE concurrence, the orbiter carried 'Chinese souvenirs,' according to a history of the AMS-01 mission, including a gold-plated memorial tablet with an inscription by 'Comrade' Deng Xiaoping' and a copper tablet engraved with the name of the Chinese Academy of Sciences and the Institute of High Energy Physics in Beijing, a facility tied closely to the Chinese military. The sprawling complex is the biggest and most comprehensive fundamental research center in China, according to U.S. defense analysts.

Other Chinese facilities that had a hands-on role in the assembly and test of the AMS hardware include Beijing's Satellite Environmental Engineering Institute.

A closer look

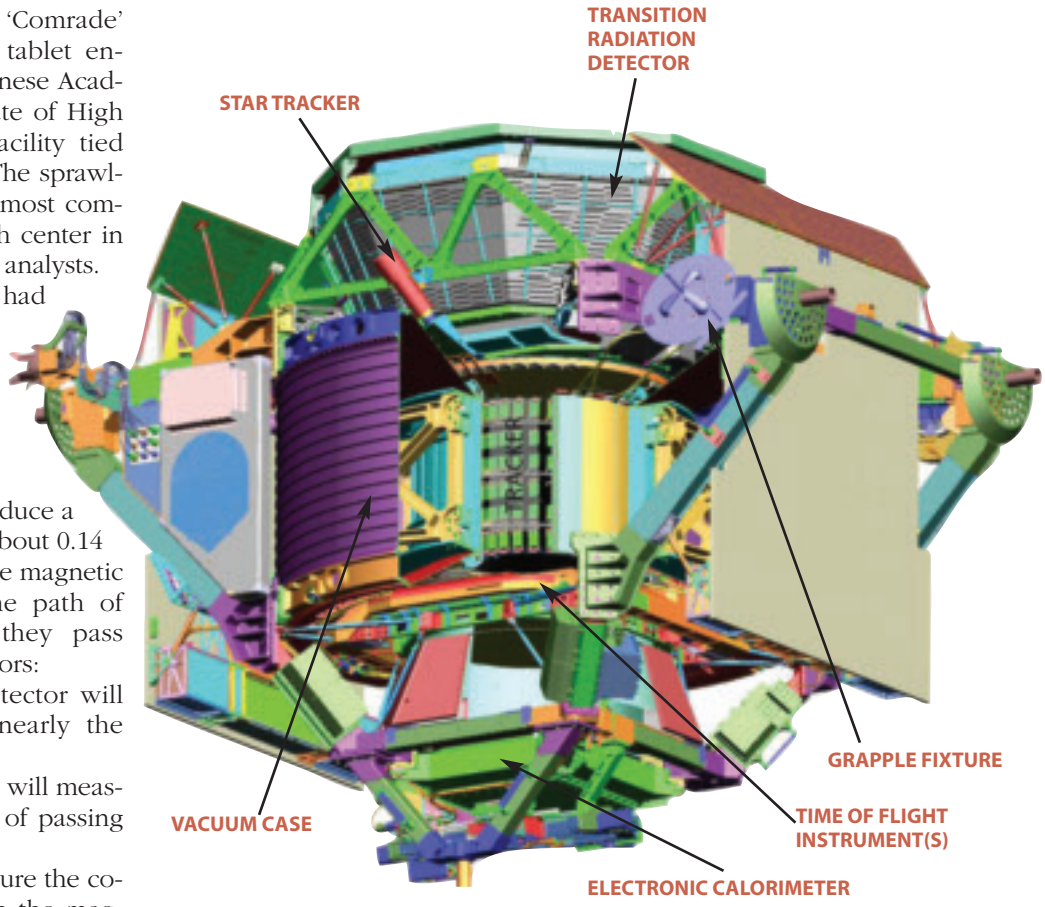
The permanent magnets will produce a strong, uniform magnetic field (about 0.14 Tesla) over a volume of 1 m^3. The magnetic field will be used to bend the path of charged cosmic particles as they pass through different types of detectors:

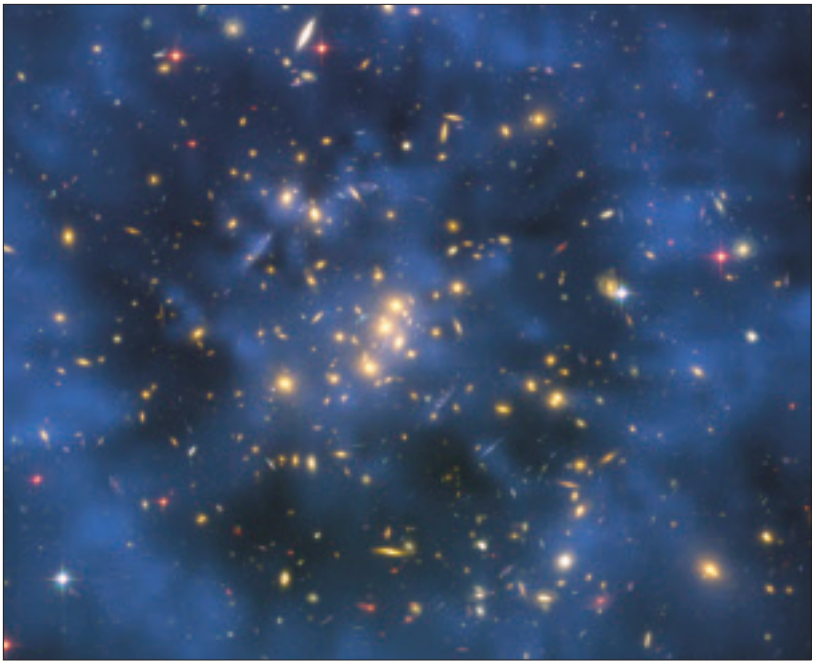
- The transition radiation detector will measure particles passing at nearly the speed of light.
- The time of flight instrument will measure the charge and the velocity of passing particles.
- The silicon tracker will measure the coordinates of charged particles in the magnetic field.

MIT Nobel Laureate Samuel Ting stands in the middle of the covered AMS-02 that he conceived.

- The electromagnetic calorimeter will measure the energy and coordinates of electrons, positrons, and gamma rays.

With over 300,000 data channels, the AMS-02 instrument will gather an extremely large amount of data that will be processed and sent to Earth using the ISS power, communication, and data infrastructure.





The Hubble Space Telescope images a ghostly ring caused by the gravitational pull of dark matter. The 2.6-million-light-year-wide ring was formed long ago during a titanic collision between two massive galaxy clusters. Though astronomers cannot see dark matter, they can infer its existence in galaxy clusters by observing how its gravity bends the light of stars, and that is what is seen here. The features are 5 billion light-years from Earth.

The AMS instrument, located in the large white cargo transfer canister, is elevated for transfer into Endeavour several weeks prior to launch.

The critical invisible

Particles of dark matter and its associated dark energy are the most enigmatic, invisible, yet critical elements in the cosmos. This is because they totally dominate the structure of the universe.

The visible matter in the universe adds up to less than 5% of the total mass that is known to exist, based on many other observations. The other 95% of the mass is dark—either dark matter (which is estimated at 20% of the universe by weight), or dark energy, which makes up the balance. The exact nature of each is still unknown. The AMS-02 detectors are geared to solving major questions about them.

According to AMS researchers, one of the leading candidates for dark matter is the neutralino particle. If neutralinos exist, they should be colliding with each other and giving off charged particles that can be detected by AMS-02. Any peaks in the background positron, antiproton, or gamma flux could signal the presence of neutralinos or other dark matter candidates.

The detection of antimatter would also be a major cosmological discovery. All evidence currently indicates that the universe is made of matter; however, the Big Bang theory requires equal amounts of matter and antimatter. Theories that explain this apparent asymmetry violate other measurements. Whether or not there is significant antimatter is one of the fundamental questions of the origin and nature of the universe. Any observations by AMS-02 of an antihelium nucleus would provide strong evidence for the existence of antimatter, AMS researchers believe.

Finding a flight

AMS-02 successfully completed final integration and operational testing at the European Organization for Nuclear Research (CERN), where it was tested with powerful nuclear particle beams generated by CERN particle accelerators. The instrument was then shipped to ESA's European Space Research and Technology Center in the Netherlands, where it underwent thermal vacuum, electromagnetic compatibility, and interference testing. Then, after another round of testing at CERN, it was delivered to Kennedy Space Center on board a USAF C-5M Super Galaxy.

For several years it was uncertain if AMS-02 would ever be launched, because it was not manifested to fly on any of the remaining shuttle flights. After the 2003 Columbia reentry accident, several flights, including that of AMS-02, were removed from the manifest. But in May 2008 a bill was proposed to launch AMS-02 to ISS on an additional shuttle flight in 2010 or 2011. The bill was signed into law by President George W. Bush in October 2008, well before the AMS team decided to fill AMS-02 with 2 tons of Chinese magnets divided into 4,000 components.

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At the Kennedy Space Center prior to launch, Ting said he did not know exactly what to expect, but that he had several ideas of what he hopes to find using the AMS. One hope is that the AMS data will open up an entirely new field of particle physics. Up until now, he said, the study of cosmic rays has been limited to measuring light using telescopes and instruments like those on NASA's Hubble Space Telescope. "The AMS is to be the first to study charged particles in space," he noted.

Ting also hopes that the particles recorded by AMS prove the existence of a parallel universe made up of antimatter, or particles that are, in electrical charge and magnetic properties, the exact opposite of ordinary particles. Such a universe has been theorized but not proven. The discovery of massive amounts of antimatter could answer fundamental questions about the origin of the universe. "Unless you do the experiments, you don't know who is right," Ting explained.