Scientists report hint of dark matter in first results from $2 billion cosmic ray detector (Update 4)

April 3 2013

This undated file image provided by the European Space Agency ESA on Wednesday April 3, 2013 shows the International Space Station in the sunlight. A $2 billion cosmic ray detector on the International Space Station has found the footprint of something that could be dark matter, the mysterious substance that is believed to hold the cosmos together but has never been directly observed, scientists say. But the first results from the Alpha Magnetic Spectrometer, known by its acronym AMS, are almost as enigmatic as dark matter itself. They show evidence of new physics phenomena that could be the strange and unknown dark matter or could be energy that originates from pulsars, scientists at the European particle physics laboratory near Geneva announced Wednesday

April 3, 2013. (AP Photo/NASA/European Space Agency ESA. Keystone)

It is one of the cosmos' most mysterious unsolved cases: dark matter. It is supposedly what holds the universe together. We can't see it, but scientists are pretty sure it's out there.

Led by a dogged, Nobel Prize-winning gumshoe who has spent 18 years on the case, scientists put a $2 billion detector aboard the International Space Station to try to track down the stuff. And after two years, the first evidence came in Wednesday: tantalizing cosmic footprints that seem to have been left by dark matter.

But the evidence isn't enough to declare the case closed. The footprints could have come from another, more conventional suspect: a pulsar, or a rotating, radiation-emitting star.

The Sam Spade in the investigation, physicist and Nobel laureate Sam Ting of the Massachusetts Institute of Technology, said he expects a more definitive answer in a matter of months. He confidently promised: "There is no question we're going to solve this problem."

"It's a tantalizing hint," said California Institute of Technology physicist Sean Carroll, who was not part of the team. "It's a sign of something." But he can't quite say what that something is. It doesn't eliminate the other suspect, pulsars, he added.

The results from the Alpha Magnetic Spectrometer, or AMS, are significant because dark matter is thought to make up about a quarter of all the matter in the universe.

In this July 25, 2012 file picture Director general of CERN Rolf-Dieter Heuer, left, Nobel laureate and AMS spokesperson Samuel C.C. Ting, right, and Mark Kelly, NASA astronaut and commander of mission STS-134, center, brief the media at the Alpha Magnetic Spectrometer (AMS) Payload Operations and Command Center (POCC) at the European Organization for Nuclear Research (CERN) in Meyrin near Geneva, Switzerland. A US $2 billion experiment on the International Space Station is on the verge of explaining one of the more mysterious building blocks of the universe: The dark matter that helps hold the cosmos together. An international team of scientists says the cosmic ray detector has found the first hint of dark matter, which has never yet been directly observed. The team said Wednesday its first results from the Alpha Magnetic Spectrometer, flown into space two years ago, show evidence of a new physics phenomena that could be the strange and unknown matter. Nobel-winning physicist Samuel Ting, who leads the team at the European particle physics laboratory near Geneva, says he expects a more conclusive answer within months. The findings are based on an excess of positrons positively charged subatomic particles. (AP Photo/Keystone/Martial Trezzini,File)

"We live in a sea of dark matter," said Michael Salamon, who runs the AMS program for the U.S. Energy Department. Unraveling the mystery of dark matter could help scientists better understand the composition of our universe and, more particularly, what holds galaxies together.

Ting announced the findings in Geneva at the European Organization for Nuclear Research, the particle physics laboratory known as CERN.

The 7-ton detector with a 3-foot magnet ring at its core was sent into space in 2011 in a shuttle mission commanded by astronaut Mark Kelly while his wife, then-Rep. Gabrielle Giffords, was recovering from a gunshot wound to the head. The device is transmitting its data to CERN, where it is being analyzed.

In this undated picture made available by NASA, a technician examines the Alpha Magnetic Spectrometer at Kennedy Space Center in Cape Canaveral, Fla.. The cosmic ray detector was mounted on the International Space Station, searched the universe and shall help to explain how everything came to be.

CERN , the European Organization for Nuclear Research, released first results of the experiment Wednesday April 3, 2013. (AP Photo/NASA, Glenn Benson)

For 80 years scientists have theorized the existence of dark matter but have never actually observed it directly. They have looked for it in accelerators that smash particles together at high speed. No luck. They've looked deep underground with special detectors. Again no luck.

Then there's a third way: looking in space for the results of rare dark matter collisions. If particles of dark matter crash and annihilate each other, they should leave a footprint of positrons—the anti-matter version of electrons—at high energy levels. That's what Ting and AMS are looking for.

They found some. But they could also be signs of pulsars, Ting and others concede. What's key is the curve of the plot of those positrons. If the curve is one shape, it points to dark matter. If it's another, it points to pulsars. Ting said they should know the curve—and the suspect—soon.

This undated image shows an artist's concept of the Alpha Magnetic Spectrometer, rounded module at left, installed on the International Space Station provided by NASA. The cosmic ray detector searched the universe and shall help to explain how everything came to be. CERN , the European Organization for Nuclear Research, released first results of the experiment Wednesday April 3, 2013. (AP Photo/NASA)

The instrument will be measuring cosmic rays, where the footprints are found, until 2020 or so.

Other scientists praised the results and looked forward to more.

"This is an 80-year-old detective story and we are getting close to the end," said University of Chicago physicist Michael Turner, one of the giants in the field of dark matter. "This is a tantalizing clue and further results from AMS could finish the story."

CERN announcement is below:

The Alpha Magnetic Spectrometer (AMS) Collaboration announces the publication of its first physics result in *Physical Review Letters*. The AMS Experiment is the most powerful and sensitive particle physics spectrometer ever deployed in space. As seen in Figure 1, AMS is located on the exterior of the International Space Station (ISS) and since its installation on 19 May 2011 it has measured over 30 billion cosmic rays at energies up to trillions of electron volts. Its permanent magnet and array of precision particle detectors collect and identify charged cosmic rays passing through AMS from the far reaches of space. Over its long duration mission on the ISS, AMS will record signals from 16 billion cosmic rays every year and transmit them to Earth for analysis by the AMS Collaboration. This is the first of many physics results to be reported.

Figure 1: From its vantage point ~260 miles (~400 km) above the Earth, the Alpha Magnetic Spectrometer (AMS) collects data from primordial cosmic rays that traverse the detector.

In the initial 18 month period of space operations, from 19 May 2011 to 10 December 2012, AMS analyzed 25 billion primary cosmic ray events. Of these, an unprecedented number, 6.8 million, were unambiguously identified as electrons and their antimatter counterpart, positrons. The 6.8 million particles observed in the energy range 0.5 to 350 GeV are the subject of the precision study reported in this first paper.

Electrons and positrons are identified by the accurate and redundant measurements provided by the various AMS instruments against a large background of protons. Positrons are clearly distinguished from this background through the robust rejection power of AMS of more than one in one million.

Currently, the total number of positrons identified by AMS, in excess of 400,000, is the largest number of energetic antimatter particles directly measured and analyzed from space. The present paper can be summarized as follows:

AMS has measured the positron fraction (ratio of the positron flux to the combined flux of positrons and electrons) in the energy range 0.5 to 350 GeV. We have observed that from 0.5 to 10 GeV, the fraction decreases with increasing energy. The fraction then increases steadily between 10 GeV to ~250 GeV. Yet the slope (rate of growth) of the positron fraction decreases by an order of magnitude from 20 to 250 GeV. At energies above 250 GeV, the spectrum appears to flatten but to study the behavior above 250 GeV requires more statistics – the data reported represents ~10% of the total expected. The positron fraction spectrum exhibits no structure nor time dependence. The positron to electron ratio shows no anisotropy indicating the energetic positrons are not coming from a preferred direction in space. Together, these features show evidence of a new physics phenomena.

Figure 2 illustrates the AMS data presented in the first publication.

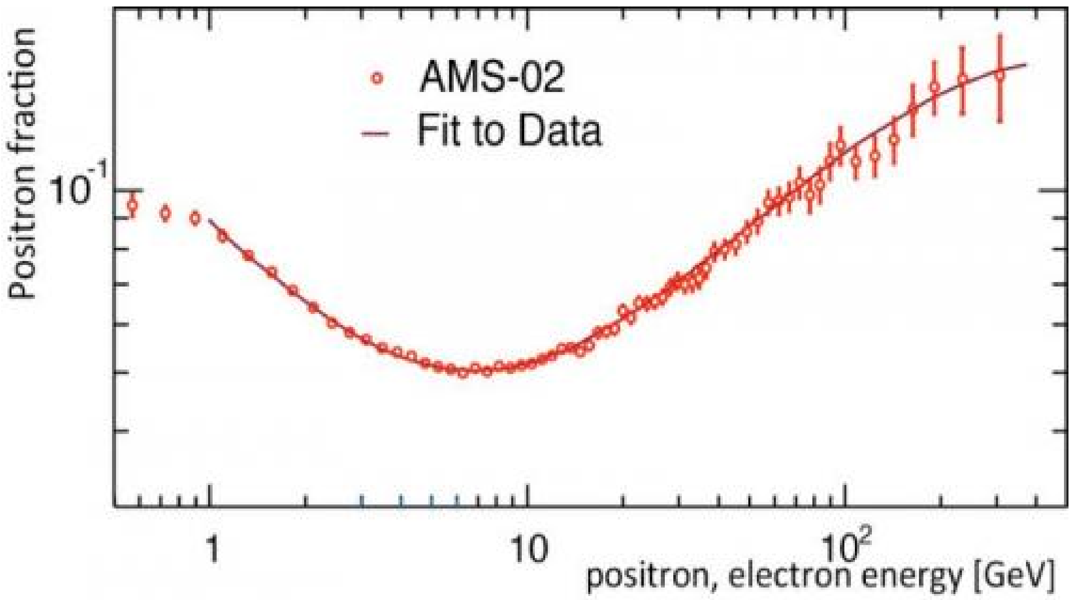

Figure 2: The positron fraction measured by AMS demonstrates excellent agreement with the model described below. Even with the high statistics, 6.8 million events, and accuracy of AMS, the fraction shows no fine structure.

The exact shape of the spectrum, as shown in Figure 2, extended to higher energies, will ultimately determine whether this spectrum originates from the collision of dark matter particles or from pulsars in the galaxy. The high level of accuracy of this data shows that AMS will soon resolve this issue.

Over the last few decades there has been much interest on the positron fraction from primary cosmic rays by both particle physicists and astrophysicists. The underlying reason for this interest is that by measuring the ratio between positrons and electrons and by studying the behavior of any excess across the energy spectrum, a better understanding of the origin of dark matter and other physics phenomena can be obtained.

The first AMS result has been analyzed using several phenomenological models, one of which is described in the paper and included in Figure 2. This model, with diffuse electron and positron components and a common source component, fits the AMS data surprisingly well. This agreement indicates that the positron fraction spectrum is consistent with electron positron fluxes each of which is the sum of its diffuse spectrum and a single energetic common source. In other words, a significant portion of the high-energy electrons and positrons originate from a common source.

AMS is a magnetic spectrometer with the ability to explore new physics because of its precision, statistics, energy range, capability to identify different particles and nuclei and its long duration in space. As shown in Figure 3, the accuracy of AMS and the high statistics available distinguish the reported positron fraction spectrum from earlier experiments.

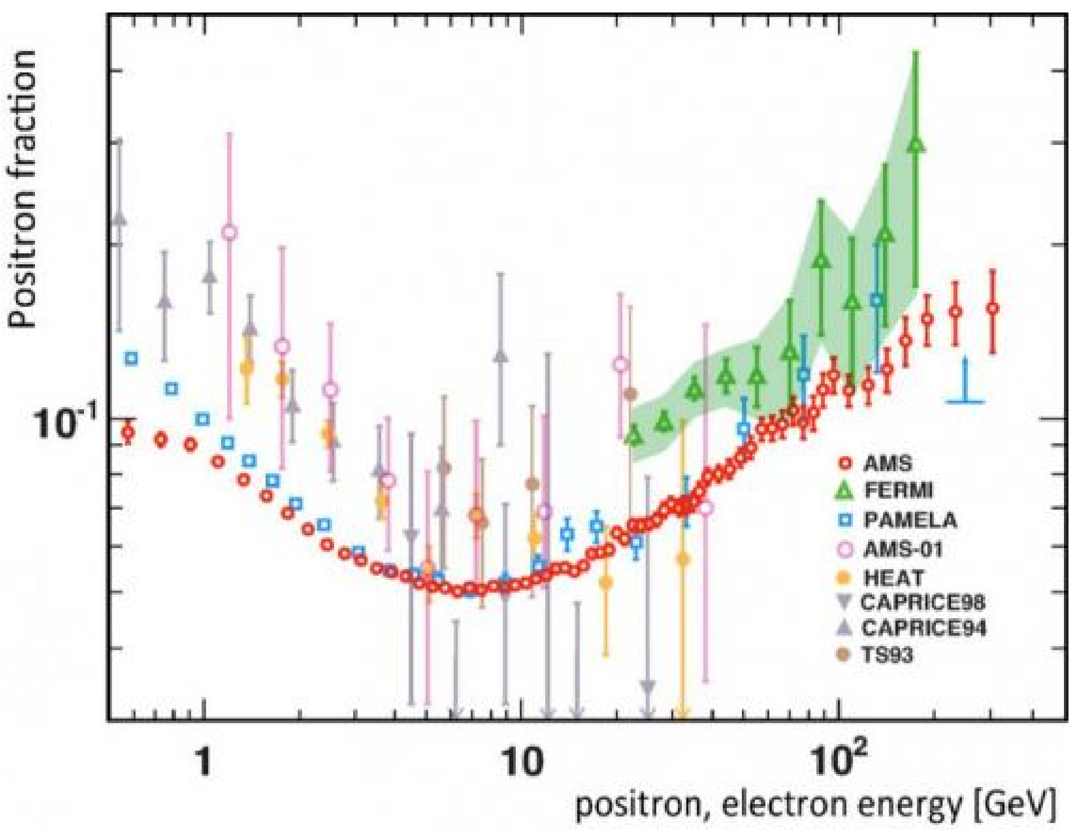

Figure 3: A comparison of AMS results with recent published measurements.

It is expected that hundreds of billions of cosmic rays will be measured by AMS throughout the lifetime of the Space Station. The volume of raw data requires a massive analysis effort. The parameters of each signal collected are meticulously reconstructed, characterized and archived before they undergo analysis by multiple independent groups of AMS physicists thus ensuring the accuracy of the physics results.

With its magnet and precision particle detectors, high accuracy and statistics, the first result of AMS, based on only ~10% of the total data expected, is clearly distinguished from earlier experiments (see References).

Background of AMS

The first publication from the AMS Experiment is a major milestone for the AMS international collaboration. Hundreds of scientists, engineers, technicians and students from all over the world have worked together for over 18 years to make AMS a reality. The collaboration represents 16 countries from Europe, Asia and North America (Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Switzerland, Romania, Russia, Turkey, China, Korea, Taiwan, Mexico and the United States) under the leadership of Nobel Laureate Samuel Ting of M.I.T. The collaboration continues to work closely with the excellent NASA AMS Project Management team from Johnson Space Center as it has throughout the entire process.

AMS is a U.S. Department of Energy sponsored particle physics experiment on the ISS under a DOE-NASA Implementing Arrangement.

AMS was constructed at universities and research institutes around the world and assembled at the European Organization for Nuclear Research, CERN, Geneva, Switzerland. It was transported to the Kennedy Space Center in August 2010 onboard a special C-5M transport aircraft of the U.S. Air Force Air Mobility Command. AMS was launched by NASA to the ISS as the primary payload onboard the final mission of space shuttle Endeavour (STS-134) on 16 May 2011. The crew of STS-134, Greg Johnson, Mike Fincke, Greg Chamitoff, Drew Feustel, Roberto Vittori under the command of Mark Kelly, successfully deployed AMS as an external attachment on the U.S. ISS National Laboratory on 19 May 2011. Once installed, AMS was powered up and immediately began collecting data from primary sources in space and these were transmitted to the AMS Payload Operations Control Center (POCC). The POCC is located at CERN, Geneva, Switzerland.

Once AMS became operational, the first task for the AMS Collaboration was to ensure that all instruments and systems performed as designed and as tested on the ground. The AMS detector, with its multiple redundancies, has proven to perform flawlessly in space. Over the last 22 months in flight, AMS collaborators have gained invaluable operational experience in running a precision spectrometer in space and mitigating the hazardous conditions to which AMS is exposed as it orbits the Earth every 90 minutes. These are conditions that are not encountered by ground-based accelerator experiments or satellite-based experiments and require constant vigilance in order to avoid irreparable damage. These include the extreme thermal variations caused by solar effects and the re-positioning of ISS onboard radiators and solar arrays. In addition, the AMS operators regularly transmit software updates from the AMS POCC at CERN to the AMS computers in space in order to match the regular upgrades of the ISS software and hardware.

With the wealth of data emitted by primary cosmic rays passing through AMS, the Collaboration will also explore other topics such as the precision measurements of the boron to carbon ratio, nuclei and antimatter nuclei, and antiprotons, precision measurements of the helium flux, proton flux and photons, as well as the search for new physics and astrophysics phenomena such as strangelets.

The AMS Collaboration will provide new, accurate information over the lifetime of the Space Station as the AMS detector continues its mission to explore new physics phenomena in the cosmos.

References

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More information: The data published in the journal *Physical Review Letters* comes from 25 billion cosmic ray events compiled since the AMS arrived at the orbiting outpost aboard the space shuttle Endeavour's final flight in 2011.

Alpha Magnetic Spectrometer: ams.nasa.gov/ , www.ams02.org/