Particle detector in space has mixed news on dark matter

Hardware on the International Space Station doesn't rule dark matter in or out.

by **Matthew Francis** - Apr 3 2013, 3:00pm CDT

The Alpha Magnetic Spectrometer (AMS-02) particle detector, mounted on the International Space Station.
NASA

The hunt for dark matter has been a difficult one. While a variety of astronomical and cosmological observations have shown roughly 80 percent of all matter doesn't interact with any form of light, physicists have yet to unambiguously detect a single dark matter particle.

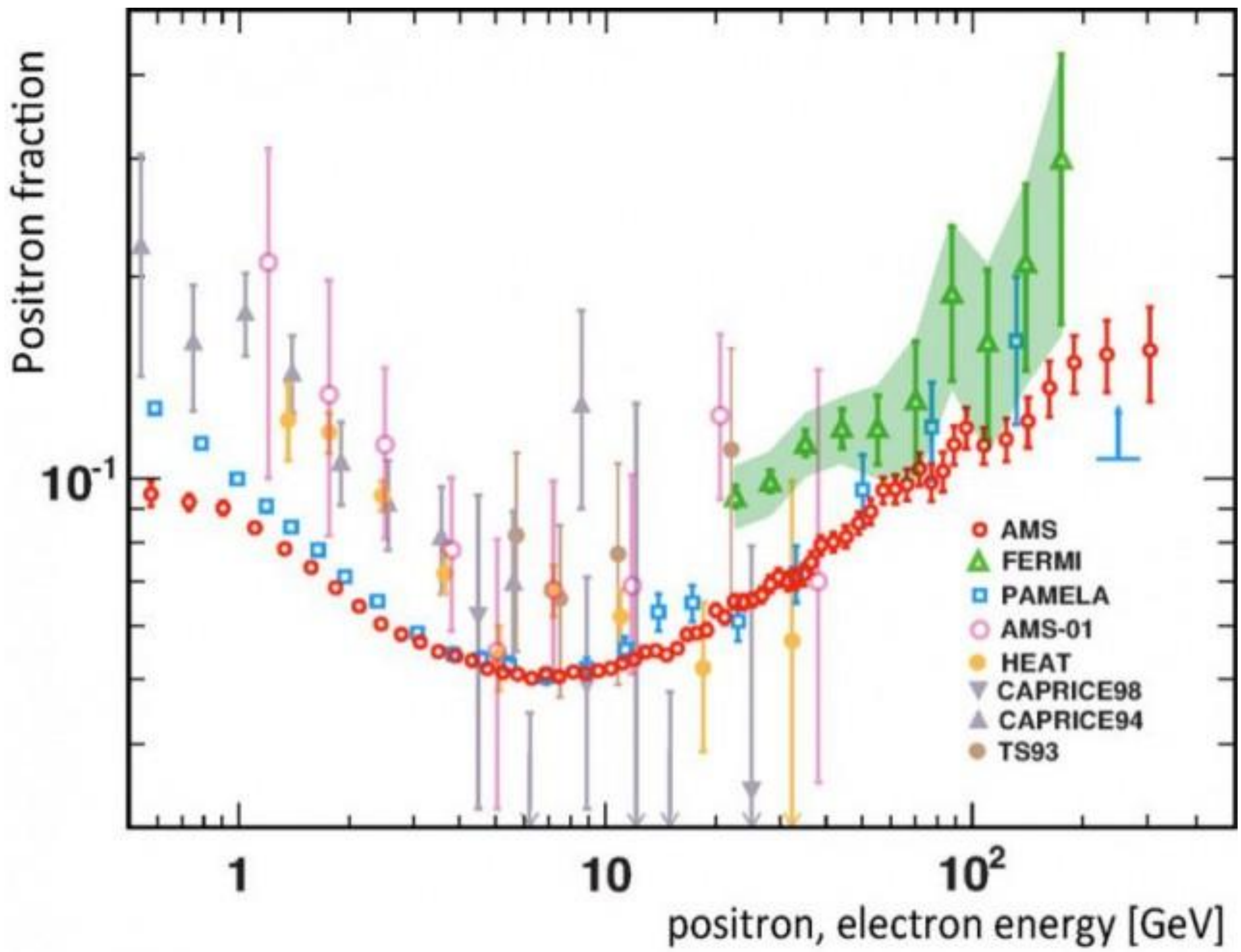
In some models, dark matter particles may collide and annihilate, just as ordinary matter and antimatter do. If these models are correct, then regions where dark matter is particularly dense—the center of the Milky Way, for example—could see collisions that produce an excess of energetic particles that we could detect from Earth.

The Alpha Magnetic Spectrometer (AMS-02) is a particle detector based on the International Space Station, designed for looking at a variety of particles from many sources, among them dark matter collisions. Recently, the AMS-02 research team announced the results of its first 18 months of data collection. These results are frustratingly ambiguous: while AMS-02 found an excess of certain type of particle expected from some models of dark matter annihilation, this excess didn't bear the hallmarks predicted for a dark matter signature. So, something interesting is going on in the AMS-02 data, but the chances of dark matter being the cause seem a bit low.

AMS-02 is a multipurpose. high-energy particle detector mounted on the International Space Station. It consists of layers of smaller detectors, designed to measure the energy and trajectory of cosmic ray particles, including high-energy photons, electrons, and positrons (electrons' antimatter partners). AMS-02 also contains a bank of high-grade magnets, which steer the path of electrically charged particles, helping to separate the contributions from different particle types. With these detectors, similar in concept to those used at the Large Hadron Collider (LHC), researchers can distinguish between positrons and protons (which have equal positive charge but different mass), electrons (which are negatively charged), and other particles.

In some models, two dark matter dark matter particles can collide, annihilate, and produce (among other things) a positron. These positrons have a specific amount of energy: their maximum energy is set by the mass of the original dark matter particles. Plotting the number of positrons as a function of their energy—known as the power spectrum—could potentially reveal the presence of dark matter annihilation and the mass of the DM particle being destroyed. That's because the power spectrum would drop sharply above the maximum available energy.

So, if dark matter is out there, we'd expect an excess of positrons compared to what we'd predict from known cosmic sources, and a distinct cutoff in that excess. There have been some hints of the excess in observations by the Fermi gamma-ray observatory and the PAMELA (Payload for Antimatter-Matter Exploration and Light-nuclei Astrophysics) experiments



Enlarge / The positron power spectrum, measuring the excess of positrons as a function of their energy. The red dots are the new data from AMS-02, while other points represent other observations. Note the absence of a sharp drop-off in positrons, which would indicate the presence of dark matter annihilation.
AMS collaboration

AMS-02 does see an excess, although it's a bit lower than these other experiments reported. But the positron power spectrum measured by AMS-02 did not exhibit a strong cutoff. Instead, the number of excess positrons rose with increasing energy, but with an ever more gentle slope, hinting at a leveling off at higher energies still. That doesn't rule out the chances of a drop beyond the edge of the current data, but it's not promising either.

Unlike instruments on a dedicated satellite, AMS-02 cannot point in arbitrary directions, thanks to being attached to the Space Station. However, over 18 months of observation, the instrument obtained data from all parts of the sky. That enabled researchers to construct information about the direction from which the positrons were coming. They found that positrons were originating from all parts of the sky equally, to 95 percent likelihood—meaning their flux is isotropic. That by itself tells us less than we might like: positrons are electrically charged, so magnetic fields in the Milky Way could steer them around, telling us little about where their source lies. It's also worth noting that the distribution of dark matter in the galaxy, especially near the center, is somewhat uncertain.

On the other hand, if the positrons were coming from pulsars—another likely candidate—their flux would likely be more skewed. The AMS-02 data could not rule out that possibility though, meaning that a more ordinary source of positrons could be responsible for their elevated levels.

With the absence of an energy cutoff, the AMS-02 results are more ambiguous than anything. It's pretty obvious that AMS-02 has not seen obvious signs of dark matter annihilation, but neither has it observed phenomena that rule them out as an explanation for the elevated positron detections. The absence of a cutoff tells us little in many ways: dark matter may not annihilate according to the model, meaning the entire experiment will never find anything, no matter how long it looks.

That's not itself a problem: measuring the positron spectrum is a worthwhile venture in its own right, and showing no DM annihilation in certain energy ranges continues to help us refine our models. The detector will continue taking data for several more years, pushing to higher energies where a telltale DM annihilation cutoff may be hiding.

Physical Review Letters, 2013. DOI: 10.1103/PhysRevLett.110.141102 (About DOIs).