Cosmic Rays, Antimatter, Dark Matter

Connecting the dots

Cosmic rays, Galactic messengers

Our planet is bombarded by high-energy protons, nuclei, and electrons coming from distant sources: **cosmic rays.** Before reaching Earth, they have traveled millions of years throughout the Galaxy. Cosmic rays tell us a story about the Universe that we would not learn from light alone. In particular, **cosmic rays contain a sprinkling of antimatter which gives us very precious information about the Universe.**

Artist's impression of a cosmic.ray that hits Earth's atmosphere [J. Yang/NSF]

Antimatter particles look the same as matter particles in many ways, but their electric charge and magnetic properties are opposite.

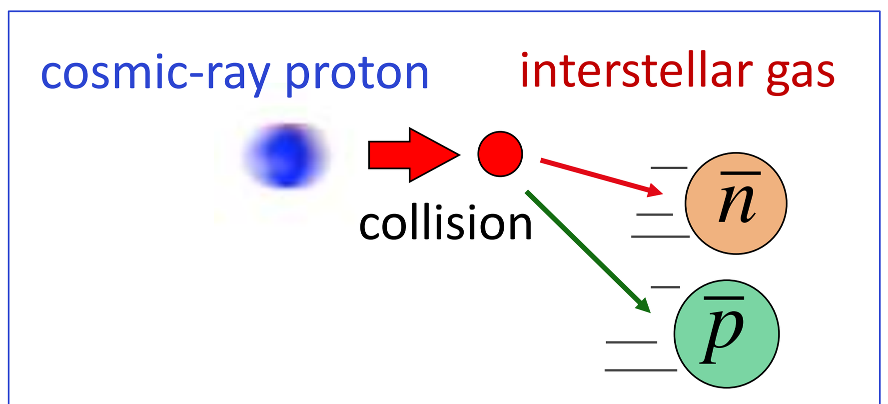
Antimatter: what is it?

Antimatter is a sort of mirror image of matter: for every kind of matter particle, an antimatter counterpart exists. It is not clear why, but it seems like there isn't that much antimatter out there. E**verything around us appears as made of matter** rather than antimatter.

In recent years, powerful instruments have been sent into space to detect antimatter particles before they get destroyed by the Earth's atmosphere. The Alpha Magnetic Spectrometer (**AMS**) experiment, in the International Space Station since 2011, has detected nearly 600,000 positrons and 350,000 antiprotons. But if the Universe is devoid of antimatter, **where do these antiparticles come from?**

→ From cosmic ray collisions?

Thanks to experiments at particle colliders, we know that if two energetic protons are smashed into one another, they can break and produce many other particles, including antiparticles. Thus, the collisions of cosmic rays against could explain the observed antimatter. This idea has be tested by calculating how many antiparticles are produced by cosmic-ray collisions in the Galaxy, and how many of them stream down on our detectors. However, there is too much antimatter that cannot be explained merely due to collisions. Very likely, there is some source of antimatter in the Galaxy that we are missing.

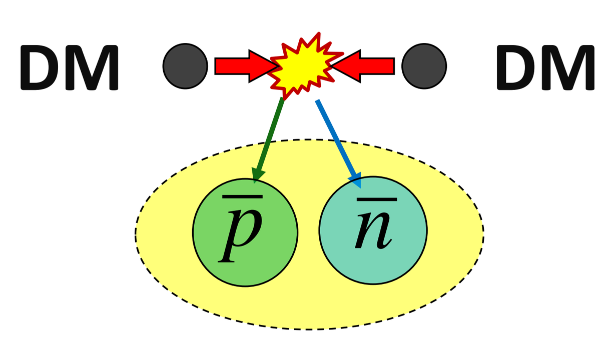


Collision of cosmic rays with the interstellar gas, leading to the production of secondary antiparticles (such as antiprotons or antineutrons)

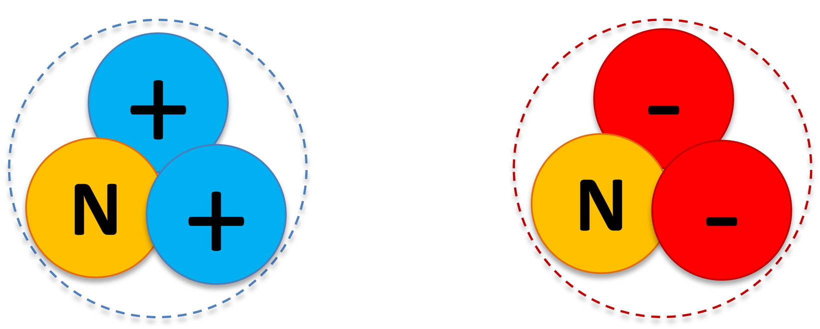
→ From dark matter annihilation?

A fascinating theory is that the excess of antiparticles comes from **dark matter**, the mysterious substance that makes up 85% of the matter content of the Universe. We believe that dark matter particles are everywhere in our Galaxy, although we don't see them. Occasionally, dark particles could collide with each other, annihilating and creating antimatter-matter pairs. So, the antimatter **excess** could be produced by the annihilation of dark matter particles. Intriguingly, the large number of antiparticles detected by AMS makes more sense if dark matter annihilation is taken into account. This looks pretty exciting, but we're still a long way o confrming it.

Is dark matter the missing source of antimatter we are searching for?



The mutual annihilation of dark matter particles may produce of antiproton and antineutrons which, in turn, can merge to form antinuclei (e.g. antideuteron)



Schematic view of an helium-3 nucleus (left) and an antihelium-3 nucleus (right)

A convincing proof would be the observation of more complex forms of antimatter: **antinuclei**. Antinuclei are composed by antiprotons and antineutrons, just like matter nuclei are composed by protons and neutrons. The simplest examples are **antideuteron** (made of one antiproton and one antineutron) and **antihelium** (two antiprotons and one antineutron). For antinuclei, the probability of being created by cosmic-ray collisions is very low, because of the huge amount of energy it would require. In contrast, dark matter annihilation could create antinuclei more easily. The detection of antinuclei could be **the smoking gun** that we have been looking for. After a half century of searching, antinuclei have never been detected in cosmic rays, but their search is ongoing.

Multichannel Investigation of Solar Modulation Effects in Galactic Cosmic Rays
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