Antimatter in the Universe

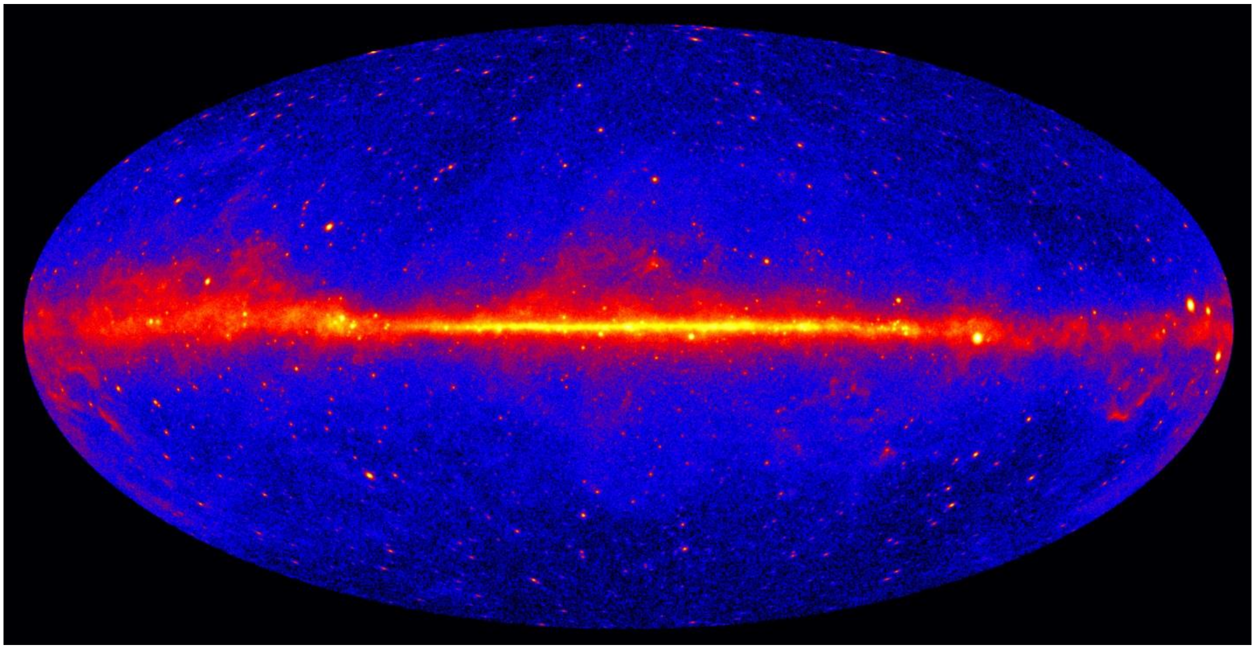
A Universe made of equal amounts of matter and antimatter can only be extremely violent, or practically empty... A single gram of antimatter released into a matter environment would unleash an amount of energy similar to that of a small atomic bomb.

Even though the Universe is not exactly a restful place, we are not immersed in such violence. The mutual annihilation of a particle and its antiparticle results in gamma radiation. By studying this type of emission produced in the Milky Way, we can estimate the maximum proportion of antimatter in our galaxy: less than one millionth billionth!

On a larger scale, it is easy to imagine that the Universe is divided into matter and antimatter areas. Regions where these areas are in contact should therefore be sources of gamma rays. The study of gamma rays coming from all over the celestial vault implies that antimatter areas, if they exist, must be located at distances greater than a few billion light-years.

However, despite this reassuring observation, physicists and astrophysicists are faced with a mystery. Both their equations and their observations indicate that the Universe was once extremely hot. The theory of general relativity even dictates that the Universe was born in a state of extreme temperature and density. Yet, at very high temperatures, a theorem in which physicists have the greatest confidence states that particles and antiparticles must exist in more strictly equal numbers as the temperature rises.

In this case, where did the initial antimatter go, and how can we explain the survival of a Universe that seems to be made entirely of matter? From the number of annihilation photons currently present in the Cosmic Microwave Background, we know that only



Credit: NASA/DOE/Fermi LAT Collaboration

about one billionth of the initial matter (and antimatter) remains. We also know that if nothing had been done to break the matter-antimatter symmetry, only a tiny fraction, one billionth billionth, of the initial matter would have survived, leaving us with a virtually empty Universe, where stars and galaxies could never have formed.

The Fermi satellite, which has been mapping cosmic gamma rays since summer 2008, and the AMS (Alpha Magnetic Spectrometer) experiment, which has been on board of the International Space Station since May 2011 to precisely measure the amount of antimatter in cosmic rays, may provide some clues to possible worlds of antimatter – worlds that are largely hypothetical for the moment.

But the light may come from particle physics. Small differences between matter and antimatter have already been identified in certain types of particles. There is still a long way to go before we unravel the mystery of the absence of antimatter in the Universe.

The sky as high-energy gamma rays

An image of the entire celestial vault after five years of observation with the Fermi satellite. The blue to yellow colour gradient reflects the increasing quantity of photons of energy $E \geq 1$ GeV coming from a given direction. Most of the radiation originates in the Milky Way galaxy, where it is produced by the interaction of cosmic rays with interstellar matter. Apart from a few gamma-ray sources correlated with active galactic nuclei, the rest of the sky shows no traces of abundant gamma-ray emissions expected to come from areas in the Universe where matter and antimatter would be in contact.

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