SLAC-PUB-13526
January 2009

How did matter gain the upper hand over antimatter?

By Helen Quinn,
SLAC National Accelerator Laboratory
Menlo Park, CA

Antimatter exists! We routinely make it in laboratories. For every familiar particle type we find a matching antiparticle with opposite charge, but exactly the same mass. For example, a positron with positive charge has the same mass as an electron; an antiproton with negative charge has the same mass as a proton. Antimatter occurs naturally all over the universe wherever high-energy particles collide.

The laws of physics for antimatter are very, very similar to those for antimatter – so far we know only one tiny difference in them, a detail of the weak interactions of quarks that earned Makoto Kobayashi and Toshihide Maskawa a share of the 2008 Nobel Prize for Physics.

Our understanding of the early Universe also tells us that after inflation ended equal amounts of matter and antimatter were produced. Today there's a lot of matter in the universe, but very little antimatter. This leaves a big question for cosmology. How did matter gain the upper hand over antimatter? It's a question at the root of our existence. Without this excess, there would be no stars, no Earth, and no us!

When a particle meets its antiparticle, they annihilate each other in a flash of radiation. This process removed all the antimatter and most of the matter as the universe expanded and cooled. All that's left today is the excess amount of matter when destruction began to dominate over production.

To get from equality to inequality for matter and antimatter requires a difference in the laws of physics between them –and some special situation where it affects the balance between them. But, when we try to use the tiny difference we know about between quark and antiquark weak interactions to generate the imbalance, it doesn't work. We find a way that it can indeed give

Published in the Sky & Telescope Magazine

Work supported in part by US Department of Energy contract DE-AC02-76SF00515

a small excess of matter over antimatter, but not nearly enough to give us all the matter we see in our universe.

We can patch up the theory by adding unknown particles to it to make a scenario that works. Indeed we can do that in two very different ways. One way adds more quark-antiquark differences. The other introduces a matter-antimatter difference that affects only neutrinos, ghostly subatomic particles that barely interact with matter. As yet we have no way to choose between these two speculative ideas; future experiments may help us decide between them.

Helen Quinn is a particle physicist at the SLAC National Accelerator Laboratory, located at Stanford University. She is coauthor (with Yossi Nir) of the recent book The Mystery of the Missing Antimatter, *which explores this question in much more detail.*