Experts from email correspondence between artists Evann Siebens and (LOoW researcher) Randy Lee Cutler and scientist Mark Scott

On 08/09/2017, at 16:33, Mark Scott wrote:

Hi Evann,

The specific interaction I want to share is this video clip:

https://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=10&cad=rja&uact=8&ved=0ahUKEwjmrIK-o8vVAhVB_mMKHZPQCooQtwIITDAJ&url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DrB9Pt05wiG8 &usg=AFQjCNEDP-hzvrDZN8Nm6Hv6KpSN_lTjVQ

This shows the Cherenkov light emitted by charged particles in our neutrino detectors (the colour indicates time, red is earlier, blue is later). Neutrinos themselves are invisible, but very, very occasionally (one in about 1,000,000,000,000,000,000 per tonne of detector) they interact to produce a charged particle. The light in the clip is what we 'see' in our detector when this happens, and what lets us try to measure time symmetry violation in our experiments.

I hope this is OK as a scheduled interaction?

Cheers

Mark

On 08/09/2017, at 05:27 PM, Randy Lee Cutler wrote:

Mark

Thank you for your contribution. The video is amazing. What happens to the neutrino at the end?   And is this phenomenon related to antimatter?

Wondering Randy

On 08/10/2017, at 9:53 AM, Mark Scott wrote:

Hi Randy,

The neutrino is converted into a charged particle (a muon in this case). The three types of neutrino (known as 'flavours') are paired to the three charged leptons (electrons, muons and taus) so a muon neutrino creates a muon when it interacts, an electron neutrino creates an electron and so on. This behaviour lets us identify which flavour neutrino interacted.

We know that as neutrinos travel they 'oscillate' between flavours - a muon neutrino will change into a tau neutrino, for example. We study this phenomenon using both neutrinos (matter) and anti-neutrinos (antimatter) and are looking to see if matter oscillates with a different frequency to antimatter. If true, this violates one of the symmetries of nature, time-reversal symmetry, and could explain why we live in a matter dominated universe.

Cheers

Mark

On 08/10/2017, at 10:01 AM, Randy Cutler wrote:

Mark

How does neutrino oscillation which I understand as symmetry violation bring you to the phenomenon of time reversal symmetry?

Thanks Randy

On 08/10/2017, at 4:23 PM, Mark Scott wrote:

Hi Randy,

Ultimately, we are trying to describe the physical laws of the universe using mathematical models. Many models are possible, but one of the things they have in common are 'symmetries'. Here a symmetry is just applying a mathematical transformation to the variables in the model. If the predictions of a model do not change under a symmetry transformation, then that is a conserved symmetry. If the model prediction changes then that symmetry is violated. As an example, if I perform an experiment now, but then repeat this same experiment tomorrow, I should get the same result. This is time-translation symmetry, and is a conserved symmetry.

In the Standard Model of particle physics (the best theory we have to date) there is one fundamental, conserved symmetry, called charge-parity-time symmetry, or CPT. This, the combination of the charge-parity and time-reversal symmetries, states that if you switch matter particles to anti-matter and reflect the universe in a mirror (charge-parity symmetry) and reverse the direction of time (time reversal) then the results of your experiment should not change.

One of the interesting features of these theories is that, if the time-reversal symmetry is violated, then the charge-parity symmetry must also be violated in order to conserve the combined CPT symmetry. Measuring time-reversal violation is therefore the same thing as measuring charge-parity violation, and measuring this charge-parity violation is the goal of T2K, the experiment that I work on.

The Standard Model does not allow you to produce matter without producing an equal quantity of anti-matter. However, the universe that we can see is entirely made up of matter, and there is no anti-matter left anywhere. So, one of the major questions we want to answer is how all of this extra matter was produced during the big bang?

If charge-parity is violated you have a mechanism to produce more matter than anti-matter. If neutrinos violate this symmetry, and by extension also violate time-reversal symmetry, then they could explain why excess matter exists in our universe.

Sorry if this explanation is a bit too simple - I'll happily go into more detail if needed!
Cheers Mark

On 08/11/2017, at 10:43 AM, Randy Cutler wrote:

Mark

For a neophyte like myself this is far from simple. Though you have explained the phenomenon very clearly. Thanks for that! My follow up question is:

How do you reflect the universe in a mirror? Does it involve a mathematical transformation?

I am sure you are super busy so if you don't have time to respond I understand. It's just that I am trying to imagine the mirror and am wondering if this is not a literal statement.

All the best Randy

On 08/11/2017, at 4:13 PM, Mark Scott wrote:

Hi Randy,

I'm glad it's clear, and thanks for asking questions! I don't often get the opportunity to talk about this stuff, and it's both useful for me and fun.

The mirror reflection is a mathematical transformation, but it is pretty much the same thing you would expect from looking in a mirror. It means reversing the direction of the spatial axes in the mathematics, so x becomes -x, y becomes -y and so on.

A real mirror performs a one-dimensional version of this reflection. If you point at a mirror then the 'mirror-you' is pointing in the opposite direction, and so the axis perpendicular to the mirror has been reversed. If you point left or right, on the other hand, 'mirror- you' points in the same direction, and so these axes have not been reversed.

Cheers!

Mark