Nothing, not anything and zero

June 6 2011

Big Bang. Credit: Eurritimia via Flickr Creative Commons

(PhysOrg.com) -- Space and time are inextricably linked, which is why astrophysicists speak of them in the same breath.

We describe the “nearest” stars as being 2,000 light “years” away; the light reaching us now left them back when humans were still fashioning flint arrowheads here on Earth. The span of the Milky Way is, similarly, 100 thousand light years across – again, a measurement of distance expressed as a measurement of time.

Many telescopes can allow us, on this basis, to see a distance reaching back 3,800 million years – to a point when the Universe was only a third of the age it is now. The very best can take us back to the beginning, and from this we know that the Universe has been expanding since it was formed more than 13 billion years ago.

Understanding what happened in between relies on a conception of space and time's indivisibility – which is roughly when things start to get a bit strange. At least, that's what happened when Gerry Gilmore, Professor of Experimental Philosophy at the University of Cambridge addressed his audience on the subject at the Hay Festival this week.

A thing, Gilmore stresses, is also defined by the space it occupies. "By saying there is 'nothing here', I am saying that there is still a space and time here, even though there is nothing," he explained. So "nothing" is not the same as "not anything". "Not anything" only happens when you take the space and time away. "Once you get your head round that little distinction, you're away," Gilmore added.

One of the more remarkable things about the Hay Festival is that about 500 people will get up in time to drive to a 10am lecture, in a tent, in a fairly damp field, on a subject as baffling and perplexing as this. Clearly aware that not everyone is of the same disposition, mathematicians have given us the number zero to help us get the hang of the nothing/not anything distinction. Zero, sometimes misunderstood as the bottom of the numerical chain, is of course in the centre of it. On either side of zero, an endless string of positive and negative numbers stretch endlessly away.

The same thing happens in space. "Space is actually a fuzzy ball full of energy," Gilmore said. "You are sitting on chairs which you think are hard, but you know that if you look hard enough the chair is not a hard piece of plastic, but a bunch of molecules with large gaps between them." This continues as we delve ever further into the microscopic depths of any material until we reach quarks – most of any material is, in fact, nothing but a magnetic field of positive and negative energy.

All of space is like that – made up of stuff that's barely there. Between elementary particles there is nothing except space-time, a balance between positive and negative energy cancelling each other out. It is, effectively, therefore, balanced at the zero point between positive and negative. But locally, that means that within space-time a concentration of either positive or negative energy can exist. If you get a lot of this locally, it can cause a bang – a very big one.

One such bang started our own Universe. Its beginning was therefore a small fluctuation in a sea of nothing, when the time equalled zero. The heat and debris that was produced following its explosion indicates that fast expansion followed.

Once it started to cool, however, an unexplained defect was revealed. What should have been half positive and half negative energy, or half matter and half anti-matter, turned out to have slightly disproportionate allocations of the two. There is, in fact, a one part in 1,000 excess of matter – so while most positive and negative particles met and cancelled each other out, forming heat and radiation, a small quantity formed into what we see around us. We are all the result of this defect.

It turns out that we are also a lot older than we think, at least in part. Most of this early matter initially turned into hydrogen – which means that the hydrogen making the water in our bodies is about 13.7 billion years old. The structure of the Universe then emerged as this matter fell into place, triggered by shockwaves created by the sound of the Big Bang, that caused it to pile up. Hydrogen, packed together at high temperatures, melted and formed into the next most stable elements in the Universe; helium, carbon and oxygen. These were cooked up inside stars.

“In a very real sense, we are all stardust,” Gilmore said. “That’s a nice way to think about yourself, as the product of that nuclear process. As my daughter tells her brother, however, ‘I’m stardust; you’re nuclear waste’.”

The study both of the expanse of space-time and the tiny, elementary particles which inhabit it, has since the last century allowed researchers to probe a strange, quantum world of anomalies where the traditional laws of physics no longer apply.

One of the early discoveries in this regard was that light behaves both as a particle and a wave. The duality was understood by James Clerk-Maxwell, when in the course of correcting equations for electro-magnetism he was able to show that magnetic fields and electric fields create one another on a mutual basis, and that light is a force that carries magnetic fields.

This does not answer the particle-wave paradox, but highlights the strangeness of the world researchers have unveiled. “The answer to whether light is a particle or a wave is fundamentally ‘yes’.” Gilmore said. “Nature is telling us that there is not one single answer to the question. We can ask simple questions but that doesn’t mean there will be simple answers. Nature actually appears to like mutually inconsistent answers to those questions.”

As an experimental philosopher, Gilmore also takes the view that the moral to this unfinished story is one that stresses the need to make progress in our knowledge of what the Universe is through scientific experiment and observation. Nature appears abstruse, because it is offering us information without any right answers. This does not suit the way in which we like to process information, categorising things according to cultural context. “What we may be misunderstanding the most is the way our own minds work,” he concluded. “The sort of answers science is producing about the Universe are simply not the answers we were expecting."

Provided by University of Cambridge