# THE DARK SIDE OF THE UNIVERSE

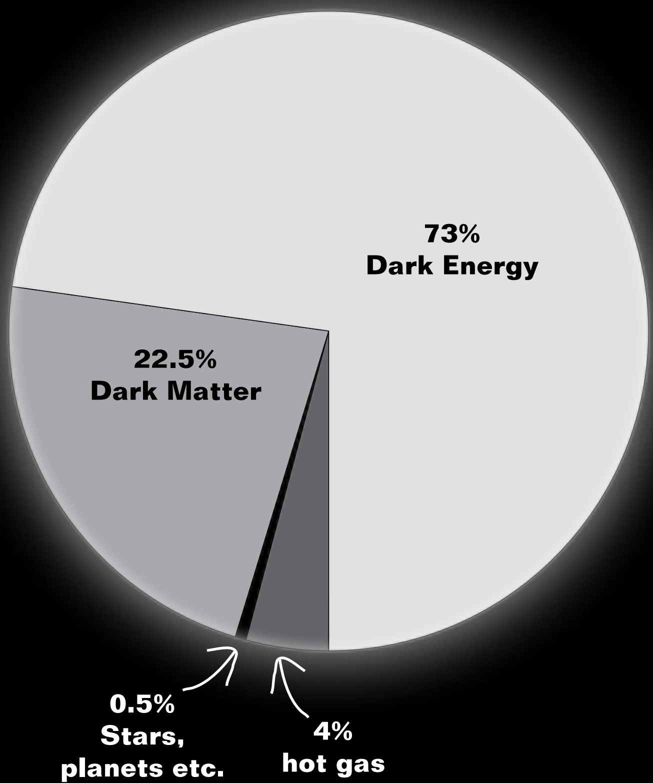
One of the simplest questions we can ask is: what is the world made of?

Long ago, the Greek Democritus postulated that everything is made of indivisible building blocks he called *atoms*. And he was right – and over the past 2,000 years we have filled in the details.

All the stuff in our everyday world is made of combinations of the 92 different types of atoms: the elements of the periodic table – hydrogen, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, and all the way up to uranium, number 92. Plants, animals, rocks, minerals, the air we breathe and everything on Earth is made of these 92 building blocks. We also know that our sun, the other planets in our solar system, and other stars far away are made of the same 92 chemical elements. We understand atoms very well, and are masters at rearranging them into all kinds of different things, including my favourite, French fries! The science of chemistry is all about building different things with atoms, a kind of 'Lego with atoms'.

Today, we know there is a whole lot more out there than just our solar system – a mindbogglingly large Universe, with billions of galaxies, each made of billions of stars and planets. So what is the Universe made of? Surprise – while our solar system and other stars and planets are made of atoms, most of the stuff in the Universe is *not*; it is made of very strange stuff – dark matter and dark energy – that we do not understand as well as atoms.

First the numbers: in the Universe as a whole, atoms account for 4.5 per cent, dark matter for 22.5 per cent, while dark energy comes in at 73 per cent. An aside: only about one in ten of those atoms is in the form of stars, planets or living things, with the rest existing in a gaseous form too hot to have made stars and planets.






Let's begin with dark matter. How do we know it is there? What is it? And how come we don't find it on Earth or even in our sun?

We know it is there because the force of its gravity holds together our galaxy, the Andromeda galaxy, and all the other big structures in the Universe. The visible part of the Andromeda galaxy sits in the middle of an enormous (ten times larger) sphere of dark matter (astronomers call it the dark halo). Without the gravity of the dark matter, most of the stars, solar systems and everything else in galaxies would go flying off into space which would be a very bad thing

At the moment we don't know exactly what the dark matter is made of (not unlike Democritus, who had an idea – atoms – but didn't have the details). But here is what we *do* know.

Dark matter particles are not made of the same parts that atoms are (protons, neutrons and electrons); it is a new form of matter! Don't be too surprised – it took nearly 200 years to identify all the different kinds of atoms, and over the course of time, many new forms of atomic matter were discovered.

Because dark matter is not made of the same pieces as atoms, it is pretty much oblivious to atoms (and vice versa). Moreover, dark matter particles are oblivious to other dark matter particles. A physicist would say that dark matter particles interact with atoms and with themselves very weakly, if at all. Because of this fact, when our galaxy and other galaxies formed, the dark matter remained in the very large and diffuse dark matter halo, while the atoms collided with one another and sank to the centre of the dark halo, eventually forming stars and planets made almost completely of atoms.

The ‘shyness’ of dark matter particles, then, is why stars, planets and we are made of atoms and not of dark matter.

Nonetheless, dark matter particles are buzzing around our neighbourhood – at any given time there is about one dark matter particle in a good-sized tea cup. And this is key to testing this bold idea. Dark matter particles are shy, but can occasionally leave a telltale signature in a very, very sensitive particle detector. For this reason, physicists have built large detectors and placed them underground (to shield them from the cosmic rays that bombard the surface of the Earth) to see if dark matter particles really do comprise our halo.

Even more exciting is creating new dark matter particles at a particle accelerator by turning energy into mass, according to Einstein’s famous formula, E = mc2.

The Large Hadron Collider in Geneva, Switzerland, the most powerful particle accelerator ever built, is trying to create and detect dark matter particles.

And satellites in the sky are looking for pieces of atoms that are created when dark matter particles in the halo occasionally collide and produce ordinary matter (the reverse of what particle accelerators are trying to do).

If one or more of these methods are successful – and I hope that at least one will be – we will be able to confirm that something other than atoms makes up the bulk of the matter in the Universe. Wow!

And now we are ready to talk about the biggest mystery in all science: *dark energy*. This is such a big puzzle that I am confident it will be around for one of you to solve. Solving it might even topple Einstein’s theory of gravity, General Relativity!



We all know that the Universe is expanding, having grown in size for the past 13.7 billion years after the Big Bang. Since Edwin Hubble discovered the expansion more than 80 years ago, astronomers have been trying to measure the slowing of the expansion due to gravity. Gravity is the force that holds us to the Earth, keeps all the planets orbiting the Sun, and is generally Nature’s cosmic glue. Gravity is an attractive force – it pulls things together, slows down balls and rockets that are launched from Earth – and so the expansion of Universe should be slowing down due to all the stuff attracting all the other stuff.

In 1998 astronomers discovered that this simple but very logical idea couldn’t be more *wrong*; they discovered that the expansion of the Universe is not slowing down, but instead it is *speeding up*. (They did this by using the time-machine aspect of telescopes: because light takes time to travel from across the Universe to us, when we look at distant objects we see them as they were long ago. Using powerful telescopes – including the Hubble Space Telescope – they were able to determine that the Universe was expanding more slowly long ago.)

How can this be? According to Einstein’s theory, some stuff – stuff even weirder than dark matter – has repulsive gravity. It goes by the name of ‘dark energy’ and could be something as simple as the energy of quantum nothingness or as weird as the influence of additional space-time dimensions! Or there may be no dark energy at all, and we need to replace Einstein’s Theory of General Relativity with something better.

Part of what makes dark energy such an important puzzle is the fact that it holds the fate of the Universe in its hands. Right now, dark energy is stepping on the gas pedal and the Universe is speeding up, suggesting that it will expand for ever, with the sky returning to darkness in about 100 billion years.

Since we don't understand dark energy, we can't rule out the possibility that it will put its foot on the brake at some time in the future, causing the Universe to recollapse.

These are all challenges for the scientists of the future – you, maybe? – to explore and understand.

*Michael*