

## Marcus Chown

# How did the universe get so complicated?



Where does the complexity of the universe come from? Why are there galaxies and stars, atoms and iPhones, rainbows and roses? A vital clue comes from seeing the reflection of your face in a window. Staring outwards, maybe you see cars driving past, trees swaying in the breeze, a dog being walked. But you also see a faint reflection of your face, because the glass is not perfectly transparent. About 95 per cent of light goes through and about 5 per cent is reflected back.

This simple observation became extremely difficult to understand at the start of the 20th century when physicists discovered that light is a stream of tiny machine-gun bullets called photons – all identical. If they are all identical, surely they should be affected identically by a window pane? Either they should all go through or they should all be reflected. There is only one way to explain 95 per cent going through and 5 per cent bouncing back: if photons have a 95 per cent chance of being transmitted and a 5 per cent chance of being turned back. But this means that if you could follow an individual photon as it headed towards a window pane, you could never know for sure whether it would be reflected or transmitted. Its behaviour is fundamentally unpredictable.

And what is true of photons is true of all denizens of the sub-microscopic world: atoms, electrons, neutrinos, everything. The universe is fundamentally unpredictable, fundamentally random. This so shocked Einstein that he famously declared: “God does not play dice with the universe.” (Less well known is Niels Bohr’s retort: “Stop telling God where to throw his dice.”) But not only was Einstein wrong, he was spectacularly wrong.

Here’s why: the universe is expanding, its constituent galaxies flying apart like pieces of cosmic shrapnel in the aftermath of the Big Bang. If the expansion is imagined running backwards, like a movie in reverse, the universe gets smaller and smaller. But the universe is “quantum” – which means it is not only unpredictable but grainy. Everything comes in “quanta” – indivisible grains that cannot be cut any smaller: matter, energy, even space. So, if you could see space on the smallest scale with some kind of supermicroscope it would look like a chessboard, with squares that could not be made any smaller.

Now, if we imagine the space shrinking as we run the

expansion of the universe backwards, the chessboard gets smaller but the chess squares cannot shrink. So there are fewer and fewer of them. In fact, at the beginning of the universe, at a time known as the “inflationary epoch”, there were only about a thousand chess squares. That’s only a thousand places to either put energy or not put energy.

If you are into computers, you will understand that the universe was describable by only 1,000 bits of information. I have 16GB flash memory on my key ring. That figure denotes 16 billion bits so, on it, I could store the information for 16 million universes!

**F**ast-forward to today. In order to describe the universe, it would be necessary to record the location and type of every atom, as well as the energy state of every electron in every atom. Instead of 1,000 bits, 1 followed by 89 zeroes bits would be needed to describe the universe. So the big question is: if the universe started out so simple, with pretty much no information, where did all the information, all the complexity, come from?

This is where the window pane comes in. Information is the same as randomness. If I have a number that is non-random – say, 1 repeated a billion times – I can tell you what it is in a few words: “1 repeated a billion times”. It therefore contains hardly any information. But say I have a random number a billion digits long. To tell you it, I must tell you each and every one of the billion digits. It therefore contains a lot of information.

So here is the answer to the conundrum of where the universe’s information ultimately comes from. Every random quantum event since the Big Bang has injected information into the universe. Every time an atom spat out a photon – or did not – it injected information; every time an atomic nucleus decayed, or did not decay, it injected information.

Einstein was wrong when he said: “God does not play dice with the universe.” Not only does his metaphorical God play dice with the universe, if he did not, there would be no universe, certainly not of the complexity needed for humans to have arisen and for you to be reading these words. We live in a random reality. We live in a universe ultimately generated by the quantum roll of a dice. ●

*Marcus Chown’s What a Wonderful World: One Man’s Attempt to Explain the Big Stuff (Faber & Faber) is out now*