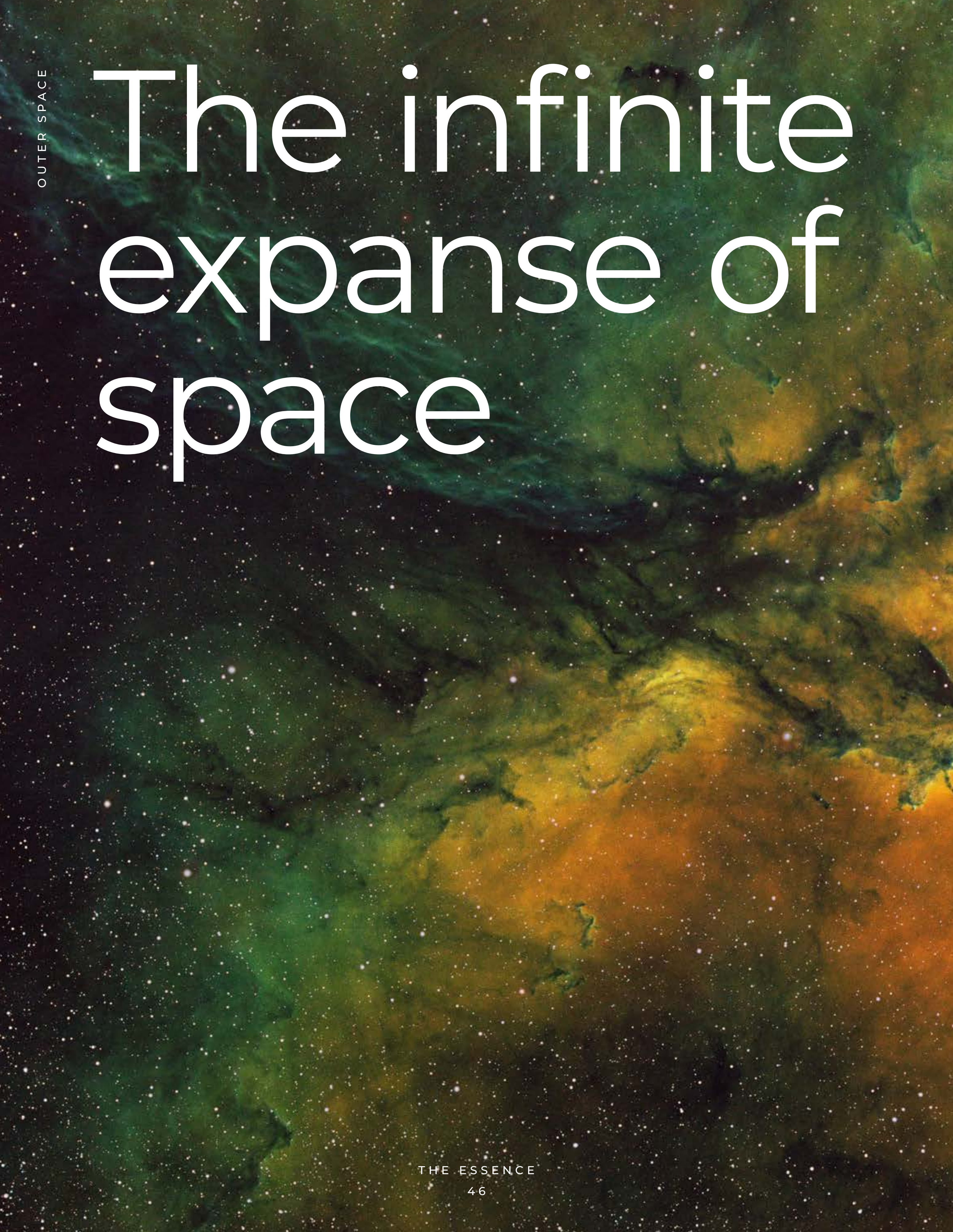


The infinite expanse of space

Author — Angel Gonzalo

Astrophysicist Ben Moore can look back on around 13.8 billion years of cosmic history and knows with mathematical certainty when the world will end. And yet he comes across as reassuringly relaxed and unruffled. The holder of the Chair of Astrophysics at the University of Zurich is someone who wants to understand the history of our universe, how it came into being and how it will continue to evolve.

Ben Moore

Professor, Director of the Institute for Theoretical Physics at the University of Zurich.

One thing we know for certain today is that our universe is expanding. This realisation allows us to draw fundamental conclusions about the past of the cosmos: if we could go back in time, the visible universe would become smaller and smaller. From a purely mathematical point of view, everything would eventually shrink to a single dot. The fact that we can assume that the universe is expanding at all is not thanks to Albert Einstein or the US astronomer Edwin Hubble, but to the Belgian priest and scientist Georges Lemaître (1894–1966). In his book 'Sternenstaub' (Stardust), which was published in 2022, Ben Moore, Professor at the Center for Theoretical Astrophysics and Cosmology at the University of Zurich, tells this and other fascinating stories about well- and lesser-known scientists who, in his opinion, retroactively deserve a Nobel Prize.

Travelling for around 13.8 billion years

The age of the universe of around 13.8 billion years was determined by combining several scientific methods, in particular by measuring cosmic background radiation and observing distant galaxies. The basis for this calculation,

Like our sun and the other planets in our solar system, the Earth was formed 4.5 billion years ago – a lengthy process, but not on a cosmic scale.

Moore explains, was introduced by Lemaître in 1927 at the Catholic University of Leuven with his groundbreaking discovery of an expanding universe. However, it was the American Allan Sandage who significantly contributed to determining the age of the universe. Sandage was an influential astronomer who was responsible for major advances in cosmology. He carried out detailed observations to more accurately determine the Hubble constant (the rate of expansion of the universe). He improved the measuring methods and reduced the uncertainties that existed in earlier determinations, thus refining the cosmic distance scale – this work was crucial to accurately measuring distances to remote galaxies. Together with other research, Sandage's work helped fine-tune the methods that ultimately led to determining the age of the universe. He was one of the pioneers who were instrumental in improving the accuracy and reliability of cosmological parameters and thus deepening our understanding of the universe. And he is also one of the 'unacknowledged heroes' in Moore's book 'Sternenstaub'.
According to today's precise measurement methods, specifically the data from the Planck satellite, the age of the universe is estimated to be around 13.8 billion years. To be precise: The latest and most accurate measurements from 2018 by the Planck mission put the age of the universe at around 13.787 ± 0.020 billion years. By comparison: When Ben Moore wrote his doctoral thesis in 1986 as a twenty-year-old, the calculated age of the universe at the time was 9 billion years with an uncertainty of ± 4 billion years. Today's precision was achieved by analysing the cosmic microwave background radiation, which represents a snapshot of the universe around 380,000 years after the Big Bang. This data, combined with other cosmological observations and models, allows us to determine the age of the universe with great precision.

We are the product of a mature universe

Humanity can be described as the product of a mature universe. The first stars that formed after the Big Bang were spheres of hydrogen and helium – the first two elements of the periodic table – and cannot produce any form of life that we know or can conceive. Living organisms are made up of long chains and rings of carbon enriched with nitrogen, oxygen, fluorine, zinc and molybdenum, to name but a few. All of these atoms, which are heavier than hydrogen, were formed in successive generations of stars that brought forth the elements of our bodies.
Like our sun and the other planets in our solar system, the Earth was formed 4.5 billion years ago – a lengthy process, but not on a cosmic scale.

When did life originate?

Genetics have discovered an elegant way to conceptually travel back in time: comparing the genomes of today's living organisms. The more similar the genomes of two species, the younger their last common ancestor (LCA). Conversely, the more different they are, the older their LCA. Palaeontology can be used to infer when the last common ancestor of humans and apes lived or when we diverged from apes in evolutionary terms. There are no theoretical limits to this 'genetic time machine'. It can be applied to modern life as a whole, thus allowing conclusions to be drawn about its origin, i.e. the last common ancestor or LUCA (Last Universal Common/Cellular Ancestor), as it is called. Nobody has seen LUCA: it is pure genetic deduction.
These studies are becoming more and more precise as more and more genomes are sequenced. The latest data allows us to calculate that LUCA lived no less than 4.2 billion years ago. Since

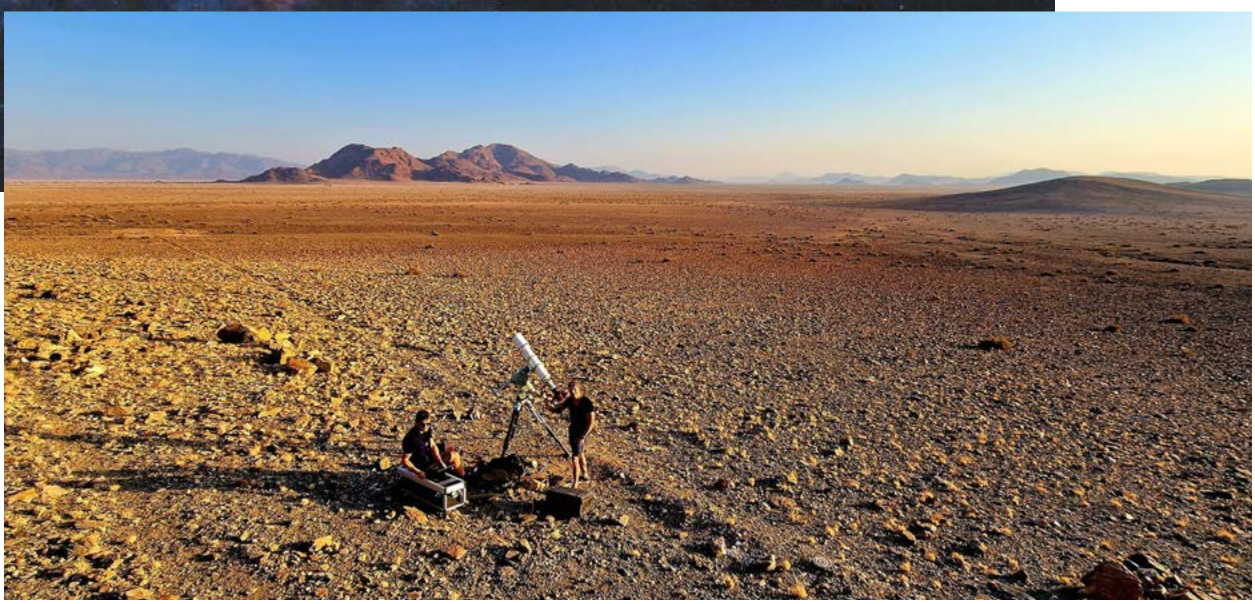
the Earth is around 4.5 billion years old, this leaves only 300 million years for the first organisms, such as bacteria, to have evolved from their mere chemical components. Animals took twice as long to evolve from single-celled organisms that were already almost as complex as we are.

The result seems to indicate that life can evolve with ease under the right physical and geological conditions. We are not the result of an unimaginable cosmic miracle, but of a process of prebiotic evolution that appears to be remarkably efficient. If it happened here, it must have happened on millions of planets in the galaxy, even if E.T. only appeared on Earth as a movie character.

What is the meaning behind it?

Do aliens exist, have they already been here or are they on their way? Ben Moore's razor-sharp mind analyses this matter-of-factly. Personally, he would be astonished if there was no life out there. Based on extrapolations, he reckons that "there are probably 40 billion planets in our galaxy alone, orbiting their respective stars in a zone where the temperature allows life to exist." Moore gives lectures on extraterrestrial life and its feasibility. No extraterrestrial, intelligent life has yet been found, but there are plenty of reasons why. Moore names two: "If it were an intelligent alien civilisation, the question is whether they would want to visit us at all. There are probably much more interesting things than us in space. Another argument is that highly developed civilisations destroy themselves before they reach the development stage of interstellar space travel." But Ben Moore's work is more concerned with robust science than speculating about where aliens might come from and what they look like. Besides teaching, he is the Swiss coordinator of ARRAKIHS, an ambitious mission selected by the European Space Agency (ESA) for its science programme. The somewhat unwieldy acronym ARRAKIHS stands for 'Analysis of Resolved Remnants of Accreted galaxies as a Key Instrument for Halo Surveys'. The project is being led by the Spanish astrophysicist Rafael Guzmán from the 'Instituto de Física de Cantabria', who studied at Durham University at the same time as Moore. Research is focusing on around one hundred nearby galaxies and their surroundings. To this end, two wide-field telescopes will be launched into space by 2030, equipped with multiple filters to take the most in-depth images ever taken of a sample of 100 nearby galaxies. While most space telescopes like Hubble or James Webb only image a tiny part of the sky (it would take over 100 images to photograph the entire full moon), the wide-angle telescopes used could pack entire nearby galaxies into one image (the equivalent of four full moons). Moore, who loves teaching and living in Switzerland, is visibly proud that Swiss industry will provide an important part of the mission's payload. The passionate mountaineer and guitar player with his own band also finds time for another hobby, cosmic photography. A few of his spectacular pictures adorn this article. They give

The infinite expanse of space...



Ben Moore prepares his equipment for cosmic photography in the Namib Desert in Namibia.

The moon, in cosmic dimensions barely a stone's throw from the Earth.

the viewer a sense of the infinity of the universe.

And how does the story of our universe end? Are we all predestined to burn up until the last speck of stardust has disappeared? “This is hard to avoid,” Moore smiles, but then reassuringly adds: “In around two billion years, the two galaxies Andromeda and our Milky Way will collide. Then it will get really uncomfortable on Earth.” Until then, we have nothing to fear except that the sky will fall on our heads, as the Chief of the Gauls Vitalstatistix in ‘Asterix and Obelix’ constantly fears, or – even worse – that Donald Trump will be re-elected President of the USA in November.

Condensed into a single day

The universe is around 14 billion years old. Ben Moore puts this into context by mentally transferring this period to a one-day timeline in order to better grasp the dimensions: At midnight, i.e. 00:00, a tiny piece of space the size of an electron began to expand rapidly, perhaps triggered by a quantum fluctuation. Space and time were formed. One hour after midnight, the first stars were born. Shortly afterwards, they too exploded and all the heavier atoms in the periodic table were created. At around 10 am, our galaxy, the Milky Way, was formed. The first single-celled organisms appeared at 10 pm. At 11.35 pm, the dinosaurs populated the Earth, although they died out again at 11.52 pm – presumably due to an asteroid impact. The entire history of humankind took place in the last second before midnight. The pyramids were built 0.03 seconds ago.

Technically speaking: Are we stardust or not?

"How old are you?" It's a simple question that we've all been asked at some point. But the answer is not so simple. In fact, it's surprising when we think about where we come from. The key is to realise that the elements that make up our bodies are older than we think, even older than our planet.

It is often said that we are stardust. This may sounds poetic, but it is not really true. When we ask ourselves how old our body is, we have to first look at what a human body actually is. It consists largely of water (around 60 % of its mass). That's H_2O, two hydrogen atoms to one oxygen atom, which means that most of the approximately 7,000 quadrillion atoms (a number with 15 zeros) that make up our body are hydrogen.

So how old are these hydrogen atoms? Again, there's no simple answer. Hydrogen atoms are made up of a proton and an electron. According to the latest calculations, protons appeared in the universe around 13.8 billion years ago. To be more precise, the protons of practically all hydrogen atoms that exist today were created in the first second after the Big Bang. From the first second of our universe, the quarks (the smallest elementary particles), which previously dominated the entire cosmos to form protons and neutrons, 'disappeared'. Electrons were already quite old at this distant point in time, created between a millionth and a billionth of a second after the Big Bang. But electrons and protons did not combine to form hydrogen until around 380,000 years after the Big Bang. 62 % of the atoms in our body make up 8 % of its mass, so they are three times as old as our planet. This indicates that we are not so much stardust as is often claimed, but rather that most of our atoms were formed shortly after the Big Bang.

Around 63 % of our body mass consists of oxygen

Oxygen is also part of the composition of our molecules and their atoms. This element is very important, because although hydrogen is the most common atom in our bodies, oxygen dominates in terms of mass. And how old is this oxygen? Astrophysicists have been asking themselves this question for decades and are looking for oxygen in ever more distant galaxies. It had already been discovered when the universe was less than 3 % of its current age.
Looking at distant galaxies means looking into the past, because they are so far away that the light takes almost an eternity to reach us. And this delay allows us to travel in space-time. Studies show that three quarters of the oxygen in the universe today was created in the first half of the history of the cosmos and another quarter later. It can be assumed that oxygen has an average age of around 10.5 billion years. Viewed in cosmic dimensions, we too are that old.

This is roughly how far we have mapped out the age of our bodies. Let's move on from this brief journey of thought through the history of our body. Let's go into when the matter that has been dancing around in the universe for eons came together in this way and acquired a 'divine' quality that philosophy and religion have already spent several millennia trying to explain. Parts of our bodies filled part of the cosmic void long before, and they will return there sooner or later.