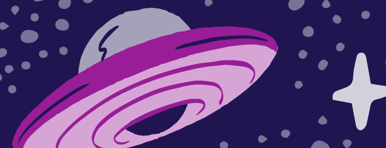
What has happened • What can happen • What *will* happen

# THE LITTLE BOOK OF COSMIC CATASTROPHES (THAT COULD END THE WORLD)

Dr Sara Webb

# What could still happen



## Chapter 5

# Armageddon by asteroid

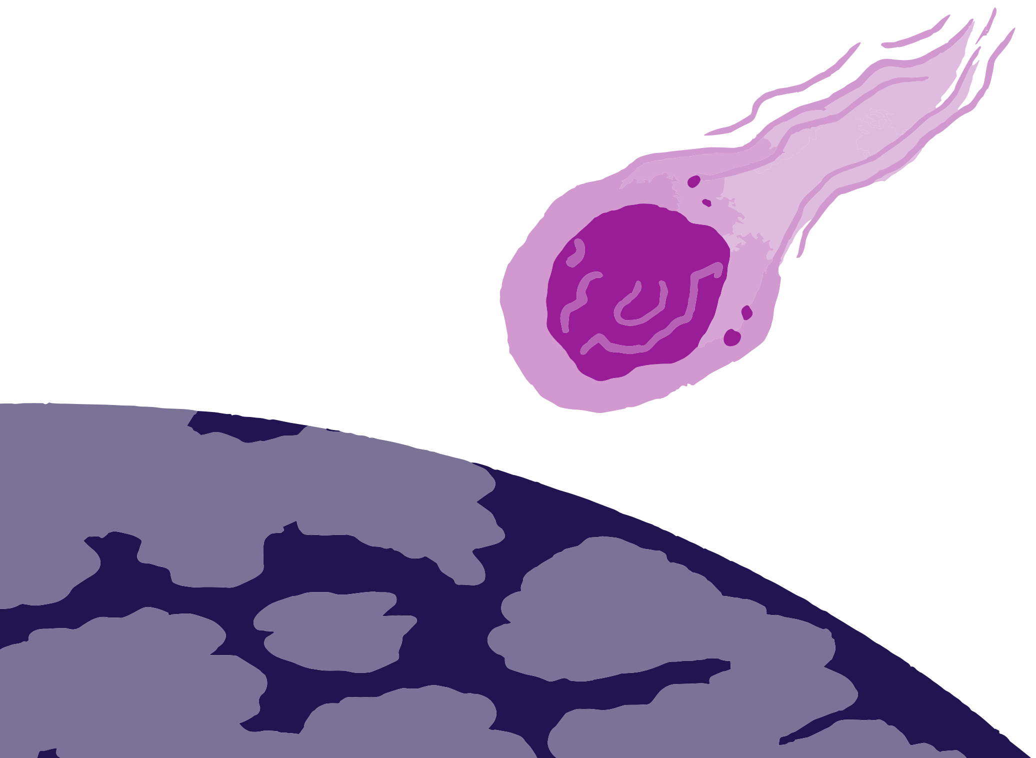
**In 1998, one of the greatest sci-fi movies of all time (in my opinion anyway) was released.**

The premise of *Armageddon* is that a giant asteroid is heading straight towards Earth and the only way to survive is to send up a rat pack of oil drillers to plant a nuclear bomb in the asteroid's core and – you guessed it – ***blow it up***.

Now … although it is an epic adventure and fun to watch, *Armageddon* is scientifically dubious, at best. Let's start with the size of the asteroid. In the movie, the killer asteroid was 1000 kilometres wide. If that sounds enormous, it absolutely is! The Chicxulub asteroid, which wiped out the dinosaurs 66 million years ago, was only 12 kilometres wide. If we went head-to-head with an *Armageddon*-sized asteroid, we wouldn't stand a chance, even with the nukes.

But what is the likelihood of Earth's destruction by asteroid? Should you sleep with one eye open and the other on the sky, just in case? The good news is that it is extremely unlikely … but not impossible!

The Solar System is home to at least 3 million individual asteroids. Most of them are stuck in orbit around the Sun between Mars and Jupiter – an area called the asteroid belt. More than a million asteroids seems like a lot compared to just eight planets, but they really aren't the monsters Hollywood makes them out to be.



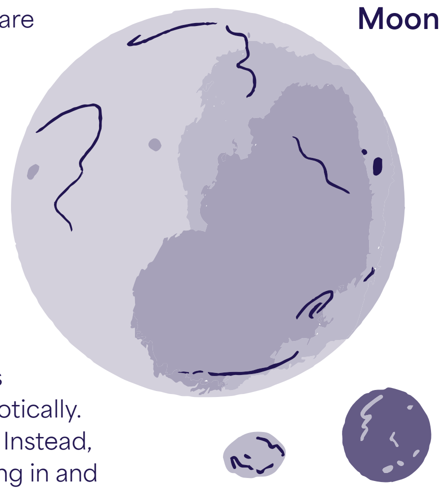
**Asteroids can be grouped into three main categories: C, S and M types.**


C-type asteroids are the most common in our solar neighbourhood, making up about 75 per cent of all asteroids. They contain a large amount of carbon and are often dark in colour, so they don't reflect large amounts of light, which can make them hard to spot.


S-type asteroids make up 17 per cent of all known asteroids and we suspect they are rich in siliceous minerals. These asteroids reflect light fairly well, and the large ones can be easily spotted with binoculars.


M-type asteroids are probably rich in metal. They probably formed in different regions of the Solar System, but are now mainly found towards the middle of the asteroid belt.

The largest asteroid in the Solar System is Vesta, an M-type asteroid that is 530 kilometres wide. Vesta is so large and bright that it was discovered in 1807 - 39 years before Neptune. (Important side note: the largest object in the asteroid belt is a dwarf planet named Ceres, but we'll focus on the asteroid Vesta.) In fact, Vesta is so massive that it contains 9 per cent of all the mass in the asteroid belt. I'm not going to lie to you - if it was flying towards Earth, we probably wouldn't survive. However, this is next to impossible. For Vesta to head in our direction, the Solar System would need some serious gravitational forces acting upon it. For now, and far into the future, Vesta is safe and sound sitting about 160 million kilometres from Earth.




Unlike Vesta, the vast majority of asteroids are under 1 kilometre in diameter. One of my favourite fun facts is that if yougrouped all the known asteroids together, they would still have less mass than the Moon. You can see why I'm not too concerned about an *Armageddon*-level event.

However ... that doesn't mean Earth is completely out of the woods.

Although most asteroids sit between Mars and Jupiter, a small handful live more chaotically. Some never settled into the asteroid belt. Instead, they orbit around the Solar System, weaving in and out of planets. The few that cross Earth's orbit are called near Earth asteroids (NEAs). These are the ones we need to track as if our lives depend on it, because they very well might.

Currently there are over 30,000 known NEAs. Of these, 8 per cent are further classified as potentially hazardous asteroids (PHAs). To be marked as a PHA, an asteroid must be over 140 metres wide and, at some point, come within 7.4 million kilometres of Earth.

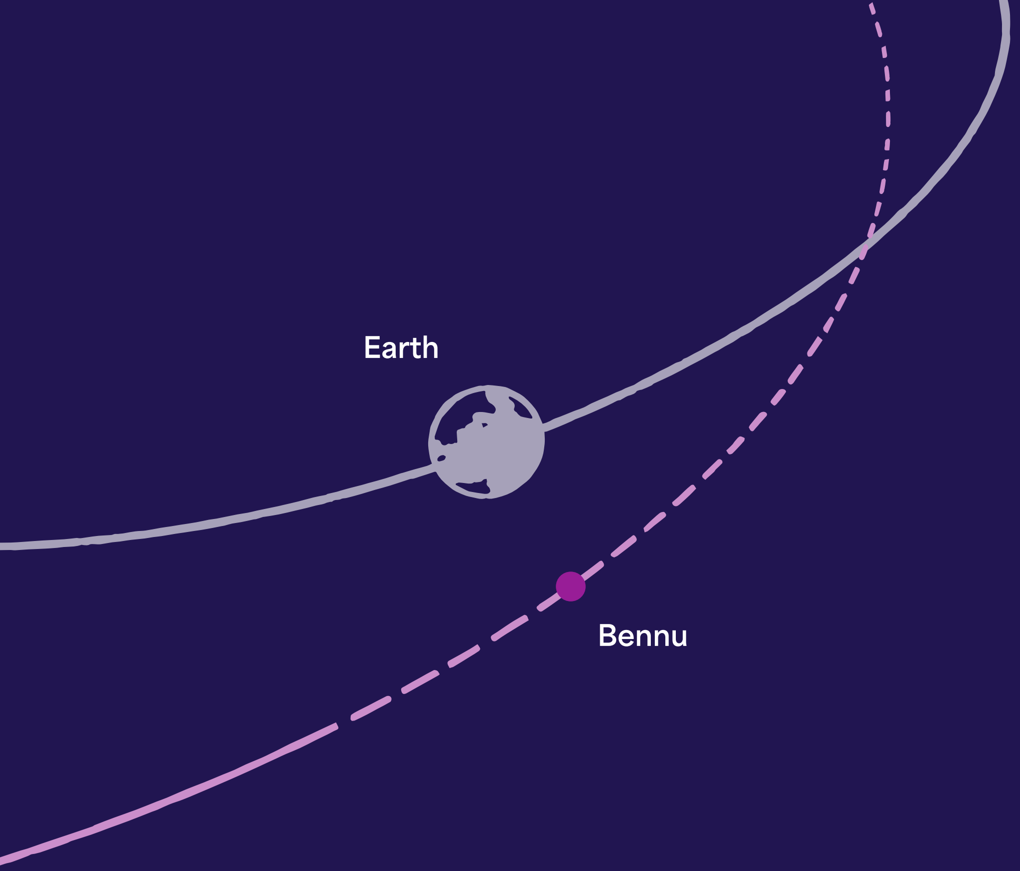
The good news is that, of all the known PHAs, we have only found 153 that are larger than 1 kilometre in diameter. The better news is that most of those large asteroids will not pose any risk to Earth for at least 100 years.



Most?

One PHA is set to have some pretty close calls with Earth in the not-too-distant future. Its name is Bennu - it was named for an ancient, mythological, Egyptian bird that was associated with the Sun, creation and rebirth. The name is fitting because, if Bennu did hit Earth, it really would be a new beginning for whatever life is here.

Bennu is a notable 490 metres wide (40 times larger than the Chicxulub asteroid), so you can be sure that astronomers are always watching it. Our calculations predict the riskiest time to live on Earth will be the year 2054, when Bennu will pass within 5.8 million kilometres of Earth. To put that distance into perspective, it's 14 times further away from Earth than the Moon is.




Bennu has a 1 in 10,000 chance of accidentally hitting Earth. With those odds, we are probably going to be just fine. But one of the most interesting (and concerning) consequences of the 2054 approach of Bennu is that, even from 5.4 million kilometres away, Bennu will be gravitationally affected by Earth. This will change the asteroid's orbit permanently, and future close approaches will have a higher chance of impacting Earth.

Astronomers and statisticians love to model potential scenarios. NASA recently said that, in the next 300 years, with multiple close approaches of Bennu to Earth expected, there may be a 1 in 1750 chance that Bennu actually hits Earth. You have a better chance of hitting a bullseye on a dart board blindfolded.

All in all, asteroids can certainly do harm to Earth, as they have in the past, but the likelihood of an asteroid causing the end of the world is next to zero. We see this with the Chicxulub asteroid and the mass extinction of the dinosaurs. The aftermath of the Chicxulub impact wasn't great, but it wasn't the end. Even after catastrophic tsunamis, wildfires and nuclear winters, Earth survived. I'd even argue that Earth actually thrived - after all, we are here. However, it is vital that we are prepared to mitigate any future impact events. Even though Earth would bounce back, humans as a species may not.

Scientists have begun testing systems to move asteroids off dangerous orbits before they get too close. Unlike in *Armageddon*, they aren't playing around with nuclear weapons - these would actually do more harm than good. If we exploded a potentially dangerous asteroid, we might accidentally create an uncontrolled debris field of smaller asteroids that could end up hitting Earth. Not so great. So what can we do instead?

One of the best ideas so far is to perform a "kinetic impact". This idea is so simple, it's beautiful. A spacecraft is flown into the potentially dangerous asteroid, and when it impacts, its momentum becomes a kinetic force that slightly alters the asteroid's orbital path. NASA has successfully tested this idea with the Double Asteroid Redirection Test (DART) mission in 2022.

The DART mission targeted Dimorphos, a moon that orbits the larger asteroid, Didymos. Dimorphos's orbit is very consistent, giving NASA the perfect opportunity to measure the effect of a kinetic impact in practice. A spacecraft weighing just over half a tonne flew straight into Dimorphos at a speed of 6.1 kilometres per second. The impact was so powerful it shortened Dimorphos's orbit around Didymos by 32 minutes. It was a promising result, and one we can use to model how much force we would need to target any asteroids that are a bit too close for comfort.

# Chapter 9
# Bad neighbours

**On Earth, a bad neighbour might play their music too loudly, but generally it isn't world-ending. But Earth might be surrounded by alien neighbours who are far less benign.**

The idea of aliens fascinates me – after all, I look out into the darkness of the cosmos on a regular basis. I am also very interested in the history of the concept of alien life. It was less than 100 years ago that we discovered there were other galaxies, and it's just over 30 years since we discovered the first exoplanet, but when did humans first look up and ponder the idea of life beyond Earth?

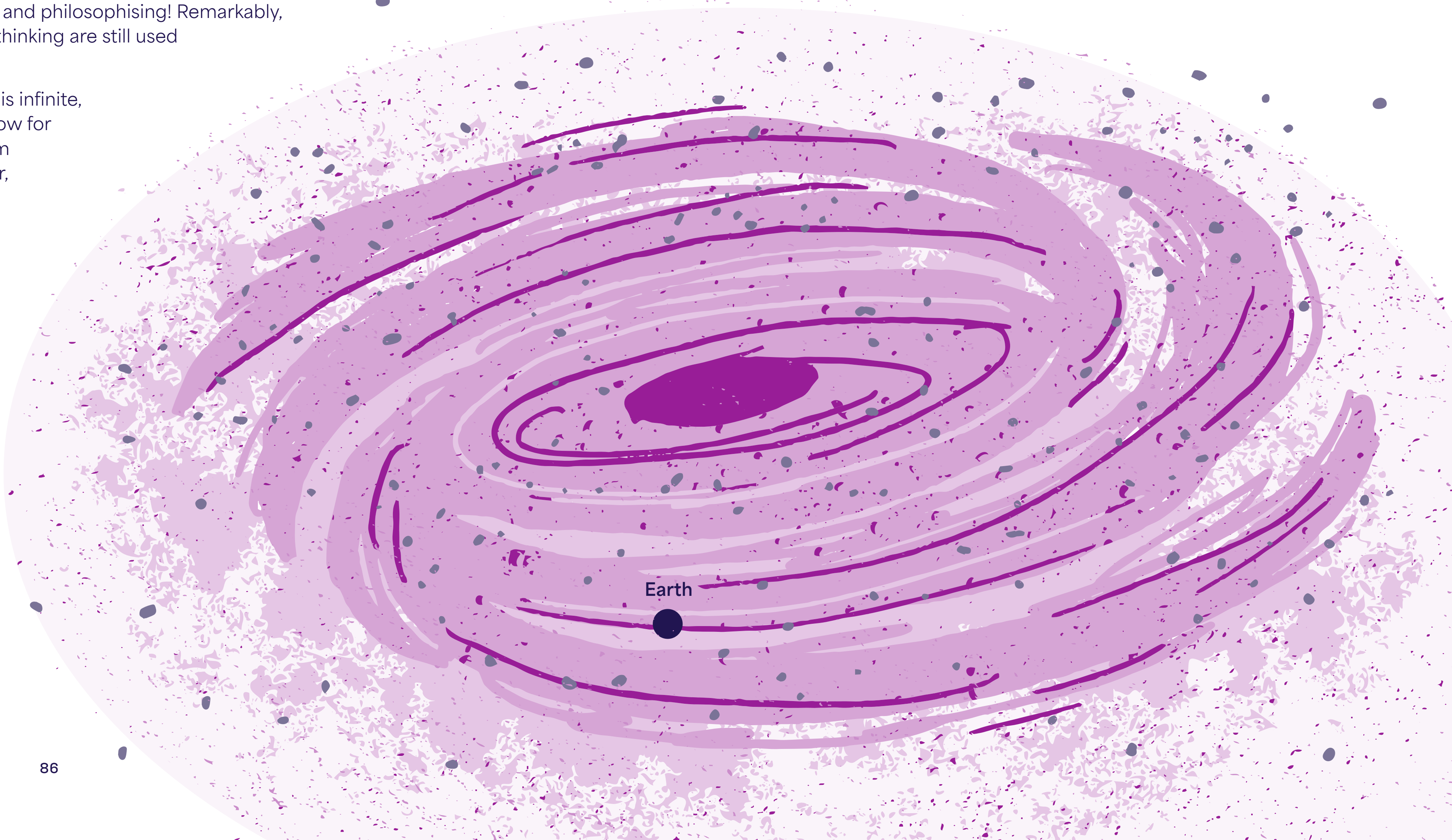
We can date it back to antiquity, specifically the works of the Roman poet and philosopher Lucretius (99–55 BCE). His only surviving written work, *De rerum natura (On the Nature of Things)*, dives into the idea of many worlds and an infinite universe. He argued that if the universe is infinite, there will surely be other worlds. And that if worlds occur by chance, when sufficient material and conditions are met, life can arise without the need for gods. Two thousand years ago! Lucretius even shocked me with his progressive thinking and philosophising! Remarkably, the very same lines of logic and thinking are still used and accepted today.

If I'm asked if I think the universe is infinite, my answer is always yes. Do I know for sure? No, absolutely not. But from everything we've observed so far, there seems to be no indication that the universe is bounded or finite. Even if it was, the observable universe is so vast it might as well be close to infinite in terms of the possibility of life beyond Earth.

Let's take a closer look at the observable universe. Be warned: the numbers we are about to talk about will hurt your brain.

## The Milky Way

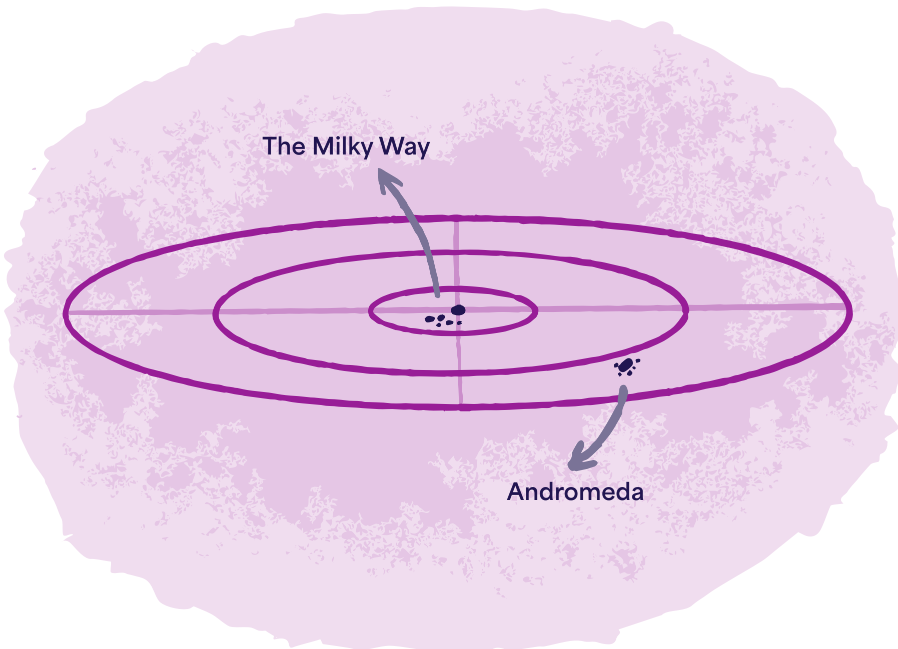
Close to home, our beautiful galaxy, the Milky Way, spans at least 100,000 light-years and is home to up to 400 billion stars, including the Sun. A good percentage of those stars could be home to planets. The lowest estimates suggest there are probably 100 billion planets in the Milky Way.



**Now let's zoom out, to the neighbourhood our galaxy lives in.**

## The local group

The Milky Way is one of 80 galaxies in a 10-million light-year area of space. Most galaxies in our local group are dwarf galaxies that orbit around larger galaxies like ours and Andromeda (we'll talk about this monster in Chapter 11). These clusters of galaxies are gravitationally bound and interact with each other over time.



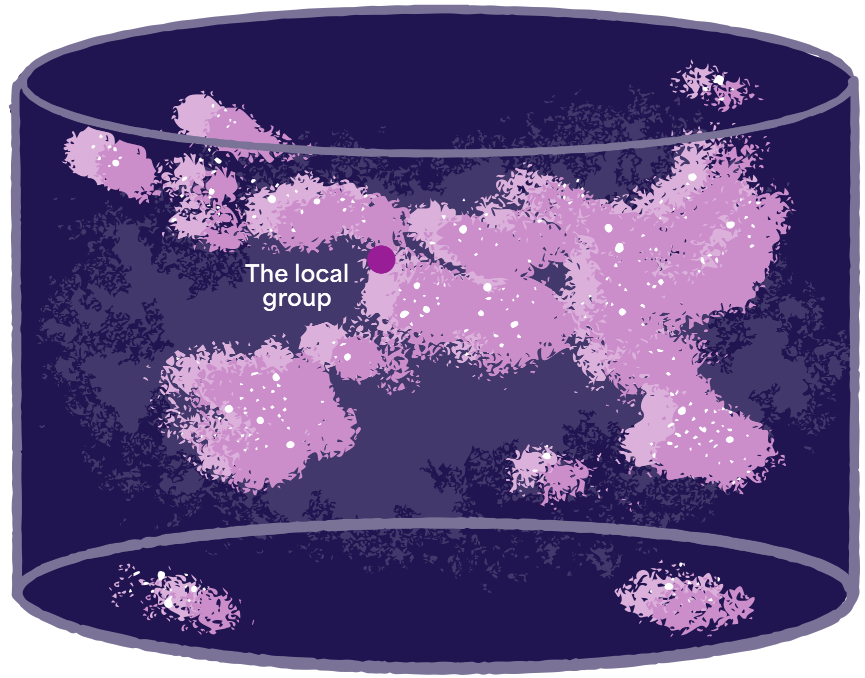

Although we don't know the exact number of stars in our local group, it's probably close to 1.5 trillion. With the majority of them bound to Andromeda, there are probably hundreds of billions of planets in this area of space. Just one of them is Earth.



## The local supercluster

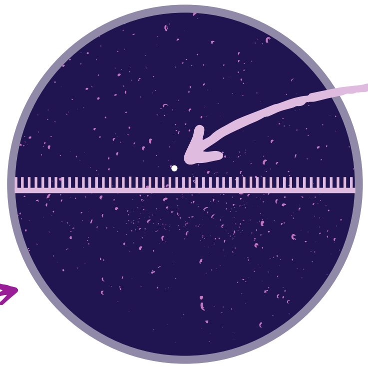
This might not surprise you, but our local group is just the beginning. In fact, it is just a drop in the ocean of galaxies that exist within our local supercluster. Our supercluster spans about 100 million light-years and houses more than 2000 galaxies, all bound within smaller local groups. These galaxies range from very small to absolutely enormous. Together, they are home to tens or hundreds of trillions of stars. The number of possible planets in this supercluster is getting close to 10 trillion. Ten trillion places that someone or something could call home.

Unlike local groups, the supercluster isn't gravitationally bound and is fairly complex in its movements.



## The observable universe

It is estimated that there are at least 10 million superclusters in the observable universe, which spans 93 billion light-years – a scale my brain can't comprehend. And when we guess how many individual galaxies and planets it contains, my headache only gets worse. It's possible there are 2 trillion galaxies in our observable universe and some estimates suggest there could be 700 quintillion planets. That's 700,000,000,000,000,000,000 planets. And we live on just one of them.




## An infinite universe

There is also a very real possibility that the universe is infinite, in which case these numbers pale in comparison to the true scale. When I think about these numbers, it doesn't seem unreasonable to assume there is absolutely life out there, somewhere. The big question is: "Is there life like us out there, and is it nearby?"

The late, great astronomer Frank Drake took this question very seriously. He calculated the likely numbers of civilisations that we could, in theory, detect via radio communications. Drake worked on the premise that humans rely significantly on radio signals for worldwide and space communication, and other civilisations probably would too. In 1961, the Drake equation was unveiled.



$$N = R_* \times f_p \times n_e \times f_1 \times f_i \times f_c \times L$$

It looks like a lot but it's pretty basic when you break it down:

$N$ = the number of civilisations in the Milky Way galaxy that we could communicate with

$R_*$ = the average number of stars in our galaxy

$f_p$ = the fraction of those stars that have planets

$n_e$ = the average number of planets in a solar system that can potentially support life

$f_1$ = the fraction of planets able to support life that develop life at some point

$f_i$ = the fraction of planets with life that develop ***intelligent*** life

$f_c$ = the fraction of civilisations that develop a technology that can release detectable signs of existence (e.g. radio signals)

$L$ = the length of time that such civilisations release detectable signals into space

We can only guess at some of these numbers and our estimates revolve around the fact that we exist in the first place. As far as we know, we are the only intelligent life in the Solar System, and we are definitely the only intelligent life we've found in our galaxy to this point.

**We can use the Drake equation to calculate the approximate number of civilisations that communication might be possible with. It turns out it could be as high as 15.5 million.**

Despite this, there is zero evidence that aliens have visited, or even attempted to contact, Earth (yet). I know some people will disagree wholeheartedly with this statement, but until there is indisputable evidence, I will remain sceptical. Why? Because of the numbers.

Yes, our universe is teeming with possible places for life to form, but it is also unimaginably big. The closest exoplanet to Earth is Proxima Centauri b. Even travelling at the speed of light (which isn't possible for matter), it would take 4.24 years to get to Proxima Centauri b.

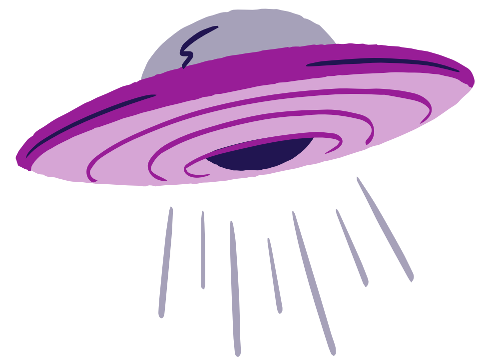
But let's be more realistic. Assume you are travelling at the fastest speed a human-made spacecraft has ever achieved. The record is currently held by the Parker Solar Probe, which is moving at a whopping 635,266 kilometres per hour. At that speed, the journey from Earth to Proxima Centauri b would take 7208 years. That's 230 generations of humans. And Proxima Centauri b is our closest neighbour! Most planets in our galaxy are many thousands of light-years away. It's not feasible to think a civilisation like ours could create sustainable methods of transport for those periods of time.

Where does this leave the possibility of an alien invasion? I'd say it is remarkably low. But what if their technology was much more sophisticated than ours? What if they had mastered physics in ways we can't even conceive? This is where we dive headfirst into science fiction territory.

Assume that there is a civilisation out there that has figured out how to traverse space without time. In theory, they could rock up to any planet in the universe in no time at all. But why would they want to? Science fiction offers three classic reasons: to steal our resources, to destroy Earth to create a hyperspace bypass, and total world domination. But are any of these likely? I'd argue no.

If there was a civilisation so advanced they could travel space-time at the drop of a hat, they probably wouldn't need the resources Earth has to offer. Nor would they need to build a hyperspace bypass. Finally, some scientists argue that, in order for a civilisation to reach such technological levels of complexity, they'd have to be peaceful. Wars and conflicts take time, energy, money and lives. A truly advanced civilisation would not risk any of those resources.





But for the sake of this book, let's play devil's advocate. How might bad galactic neighbours destroy the world?

If they wanted to get their hands on our natural resources, they might dismantle Earth piece by piece and transport it back to their home planet. If they needed to delete the Solar System to make room for a hyperspace bypass, I'd hazard a guess that a black hole would be a good method. If they wanted the Earth to be their new home, they could change our atmosphere to suit their own breathing needs, and it would all be over for us.

These ideas make for wonderful sci-fi concepts, but they are not grounded in reality. I sleep peacefully at night without worrying about potential alien invasions. You should too.