Why Does Mathematics Describe the Universe So Well?

By: Nadira Begum

1. Introduction

Have you ever thought about how, in physics, we use simple equations (like $v = f\lambda$) to describe the relationship between wave speed, frequency, and wavelength? How does this equation work for all types of waves? Why do all these natural waves follow the same mathematical relationship, and what does this suggest about the structure of reality? The Fibonacci Sequence, a sequence in which each element is the sum of the two preceding[1] elements, is not only found in maths; it can also be found in nature: for instance, in the seed head of sunflowers[2]. Why is it that this mathematical discovery appears in the natural world? This has been a question that has puzzled scientists and philosophers for centuries. Eugene Wigner, a Hungarian-American physicist, once said, “The unreasonable effectiveness of mathematics in the natural sciences.”[3] This leads to a deeper question: why does the universe obey mathematics? Nearly all scientific laws can be expressed mathematically, which could suggest that the universe is ordered mathematically.

Figure 1 – Sunflower Seed Head with Fibonacci Spiral[4]

[1] https://en.wikipedia.org/wiki/Fibonacci_ sequence
[2] https://www.bbc.co.uk/bitesize/articles/zm3rdnb#:~:text=If%20you%20cut%20into%20a,seed%20head%20of%20a%20sunflower.
[3] https://en.wikipedia.org/wiki/The_Unreasonable_Effectiveness_of_Mathematics_in_the_Natural_Sciences
[4] https://science.howstuffworks.com/math-concepts/fibonacci-nature.htm

2. To what extent do natural systems follow mathematical patterns?

As explored above, mathematical patterns appear throughout nature, from the Fibonacci sequence to fractals, which we'll discuss later. Mathematics appears both in biological and physical systems. However, there are limitations regarding the argument; often, these appearances are approximate and not exact, so we can explore how nature follows maths to a significant extent (but not perfectly).

When looking at evidence proving that nature DOES follow maths, we have already explored the Fibonacci sequence, which is the most palatable example, but it is worth mentioning fractals in nature. A fractal is a geometric shape containing detailed structure at arbitrarily small scales[5]. Perhaps one of the tastiest and striking examples of a fractal in nature, Romanesco broccoli approximates a natural fractal[6] (as it cannot be infinite). Another example is bilateral symmetry in animals; for example, butterflies demonstrate bilateral symmetry as they are symmetrical if you were to split a butterfly in half,[7] which is useful for animals as it is associated with health and evolutionary fitness, meaning an animal is more likely to find a mate if they have good bilateral symmetry.

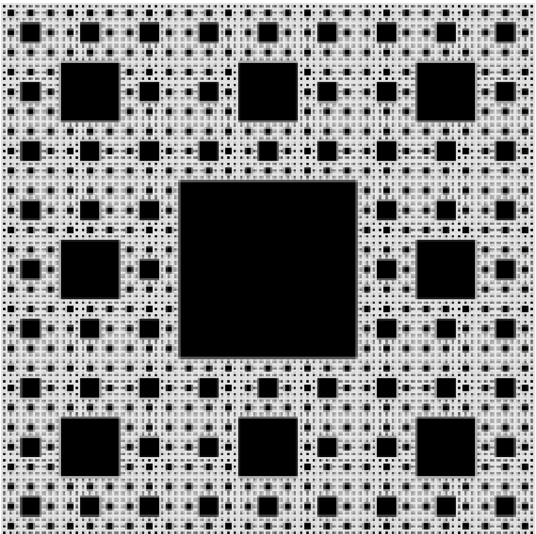

Figure 2 - Sierpinski Carpet (to level 6)[8]

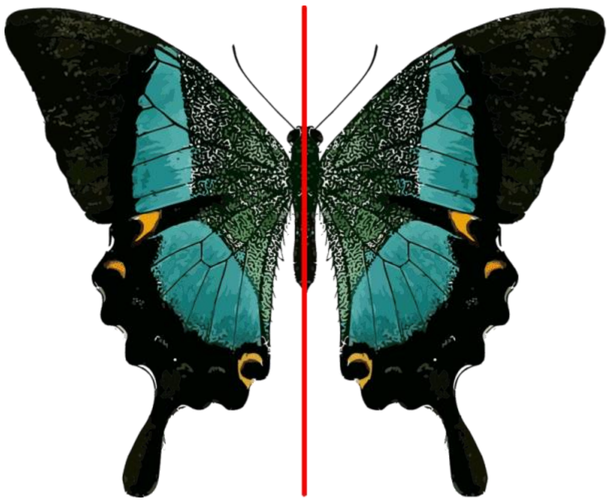

Figure 3 – Bilateral Symmetry in a Butterfly[9]

You may be questioning "why do these patterns appear in nature in so many different cases?". The short answer is that nature favours efficient structures (through natural selection), so efficient energy use, e.g. through symmetry and balance, is described by maths because maths describes optimisation and structure.

However, as mentioned earlier, there are limitations. Patterns in real life are rarely perfect due to variation in genetics, environmental conditions, and many other factors that I'm sure a biologist would be happy to discuss. Not all sunflowers follow the Fibonacci sequence

[5] https://en.wikipedia.org/wiki/Fractal
[6] https://en.wikipedia.org/wiki/Romanesco_broccoli
[7] https://www.thesill.org.uk/butterflies-moths-and-symmetry/
[8] https://en.wikipedia.org/wiki/Fractal
[9] https://flexbooks.ck12.org/cbook/ck-12-middle-school-math-concepts-grade-6/section/9.20/primary/lesson/line-of-symmetry-msm6/

exactly (so please don't go counting sunflower seeds!). The broccoli's fractal terminates at one point because it is *just* a piece of broccoli – it's physically finite. Essentially, nature likes efficiency, and maths describes efficient and optimal structures; mathematical patterns are not favoured randomly – they work because they provide advantages like energy conservation.

3. Physics, the Mandelbrot Set, and the existence of a higher power

Foreword

Often, many people **(often incorrectly)** claim that maths is irrelevant in the world of humanities, however, I would argue that maths and every other subject can be linked in a way. In this essay, I will focus particularly on the link between maths and philosophy, however, maths can be linked to any subject, (including subjects like History or English Literature, for instance, Shakespeare's use of Iambic Pentameter, or lack thereof, when emphasising certain phrases) and I would encourage you to look into it!

Sir Isaac Newton

Maths has long been used to describe the physical universe; when examining Newton's work and the foundations of calculus, you can delve into the reasons *why* he created calculus – to describe space and the universe. Eugene Wigner (discussed above) said:

"Newton ... noted that the parabola of the thrown rock's path on the earth and the circle of the moon's path in the sky are particular cases of the same mathematical object of an ellipse, and postulated the universal law of gravitation on the basis of a single, and at that time very approximate, numerical coincidence."[10]

That was a lot of complex words; essentially, Newton saw that the path of a rock being thrown looks different to the path of the Moon around the Earth (and the Earth around the

[10] https://en.wikipedia.org/wiki/The_Unreasonable_Effectiveness_of_Mathematics_in_the_Natural_Sciences

Sun), but they're pretty much the same shape, an ellipse. Why is it that something as boring and small scale as throwing a rock and watching it fall be likened to the Moon's orbit?

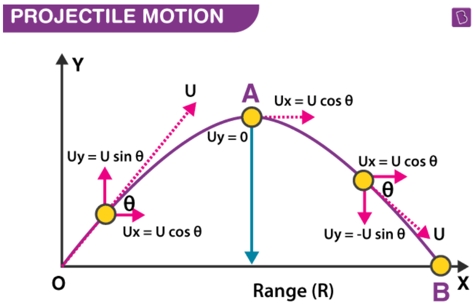

Figure 4 – Path of a Rock, being thrown up[11]

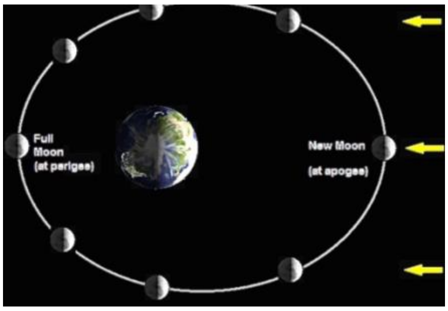

Figure 5 – The Moon's Orbit[12]

The Design Argument

The Design argument (or Teleological argument) suggests that if Earth's design makes it plausible to believe that someone or something must have designed it (a designer)[13]. It is further strengthened when we consider maths and how the universe is structured. How is it that natural laws can be described so well by using equations that have order and consistency? It's almost like this mirrors the order and consistency of the universe...

One of the most striking and truly beautiful examples of this is found in pure maths itself; the Mandelbrot set is generated by iterating a simple function on the points of the complex plane. The points that produce a cycle (the same value over and over again) fall in the set, whereas the points that diverge (give ever-growing values) lie outside it.[14] Essentially, it is a pattern formed by repeatedly using a simple rule to numbers and seeing if they remain stable or grow to be infinitely large. (*Diverge* means it will go off into infinity.) The Mandelbrot set is particularly important because it exhibits an infinitely complicated pattern that reveals progressively finer details at

[11] https://byjus.com/physics/projectile-motion/
[12] https://cosmosatyourdoorstep.com/2017/09/06/lunar-phases-and-motion/
[13] https://www.bbc.co.uk/bitesize/guides/zv2fgwx/revision/3
[14] https://math.libretexts.org/Bookshelves/ Analysis/Complex_Analysis_-_A_Visual_and_Interactive_Introduction_(Ponce_Campuzano)/05%3A_Chapter_5/5.05%3A_The_Mandelbrot_Set

increasing magnifications[15] - the more you zoom in, the more and more copies of the set you can find, and it gets more and more intricate.

The Mandelbrot Set

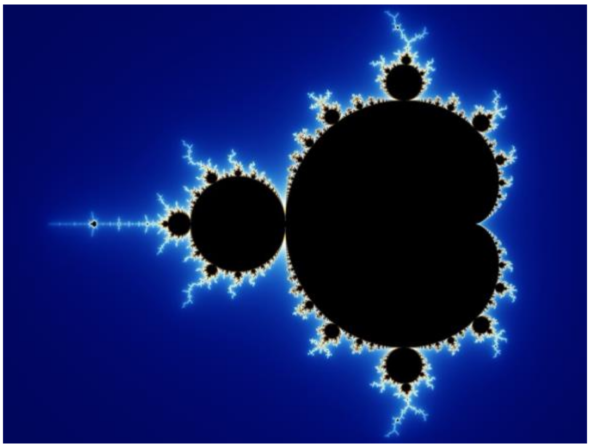

Figure 6 – The Mandelbrot set

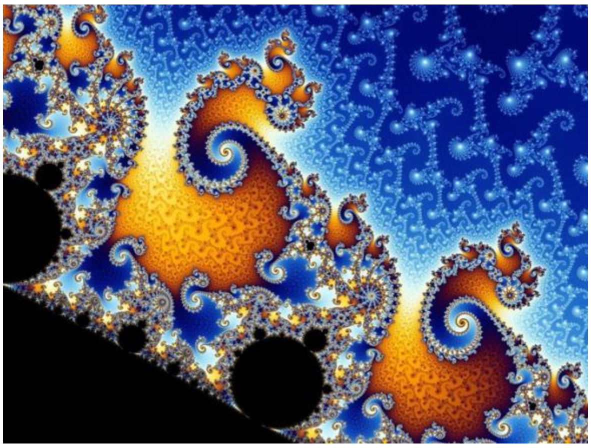

Figure 7 – Finer detail in the Mandelbrot set

Since the Mandelbrot set was discovered, we did not *invent* it, as it is infinitely complex, so it has an infinite amount of information... but where did it come from? The infinite detail of it means it was not necessarily *invented* by humans, but discovered through maths and mathematical rules… so who *actually* created it?

Philosophy – Platonism & The Universe

One perspective is that maths was *discovered,* not invented. Whether or not humans find the Mandelbrot set, it has and will always exist, but, as this is the case, *where* does it exist, and, if it exists regardless of if we see it or not, does it show that there is something beyond human creation? Something capable of producing infinite order and complexity may point to a higher intelligence. Many philosophers and mathematicians claim that mathematics exists in the non-physical world, beyond us. Dr. William Lane Craig, a philosopher, claims that, for a non-theist Platonist, "it is just inexplicable why the physical world would be imbued with a mathematical structure of these causally irrelevant, non-spatio-temporal, abstract entities." (A '*Platonist'* is someone who believes that mathematical truths exist independently of the human mind, and they are discovered.) He pretty much says that it's hard to explain why the physical world is governed by abstract maths and mathematical truths that exist outside of space and time, as discussed above. This may imply that there is a mind beyond us, as maths exists beyond us and the universe (in reality) obeys it.

Maths is abstract, not physical, whilst the universe is physical, but somehow, the universe follows maths almost perfectly – the connection is unexpected. Whilst there is no clear answer, if maths is infinitely complex, then maths is going to be beyond our understanding (transcendent)… if we can't invent maths, and we discovered it, who created it? This links back to the design argument from earlier. Maths can be seen to

[15] https://en.wikipedia.org/wiki/Mandelbrot_set

support the existing arguments for the existence of a higher power. Maths incorporates structure, suggesting that it was designed intelligently. It is also logical, consistent, and elegant – not random.

Could this be *just* a coincidence, or is there an intelligent mind behind reality? For example, with architecture, we design things for a purpose, often to make things efficient and practical. Could the same logic be applied to a creator with the intentionality of maths and the universe?

One may argue that maths doesn't necessarily *govern* reality, it just *describes* reality. For example, Stephen Hawking wrote "a physical theory is just a mathematical model and it is meaningless to ask whether it corresponds to reality"[16]. This suggests that mathematics does not govern the universe, but it provides a way for humans to interpret and describe patterns, even things as complex as systems in space – it is a tool for human understanding but not built into reality itself. Furthermore, as discussed above, maths is found in nature to an extent – nature cannot have infinite patterns, as infinity is beyond our natural world, as nature does not allow perfection like infinity, but maths does, which is why infinity exists in maths but not the natural world as we know it.

4. Conclusion

Whilst maths is undeniably powerful (I mean, it can allow for perfection like infinity!), and deeply embedded in physics, it is human framed. Why did we discover maths? Why didn't we just stop at 1+1=2? It's because humans are inherently curious, and we need an explanation for the universe. But even if maths is 'man-made' (as maths exists in the minds of humans), then why does it work so well, even in nature? Why do such simple and tidy equations describe massive things like radiation in space?

Maths alone cannot definitively prove the existence of God for certain, however, its consistency, universality and ability to describe systems and patterns could imply that there is an 'order' to the universe that is difficult to explain by coincidence *alone*. It may also imply that this 'order' exists outside of the human mind and not created by it. Whether this 'order' is an omniscient, omnipotent designer or a coincidental property of the universe is still an open question and has been debated for centuries, however, mathematics gives us strong evidence that reality is not *just* randomised.

[16] https://www.asa3.org/ASA/book_reviews/9-97.htm