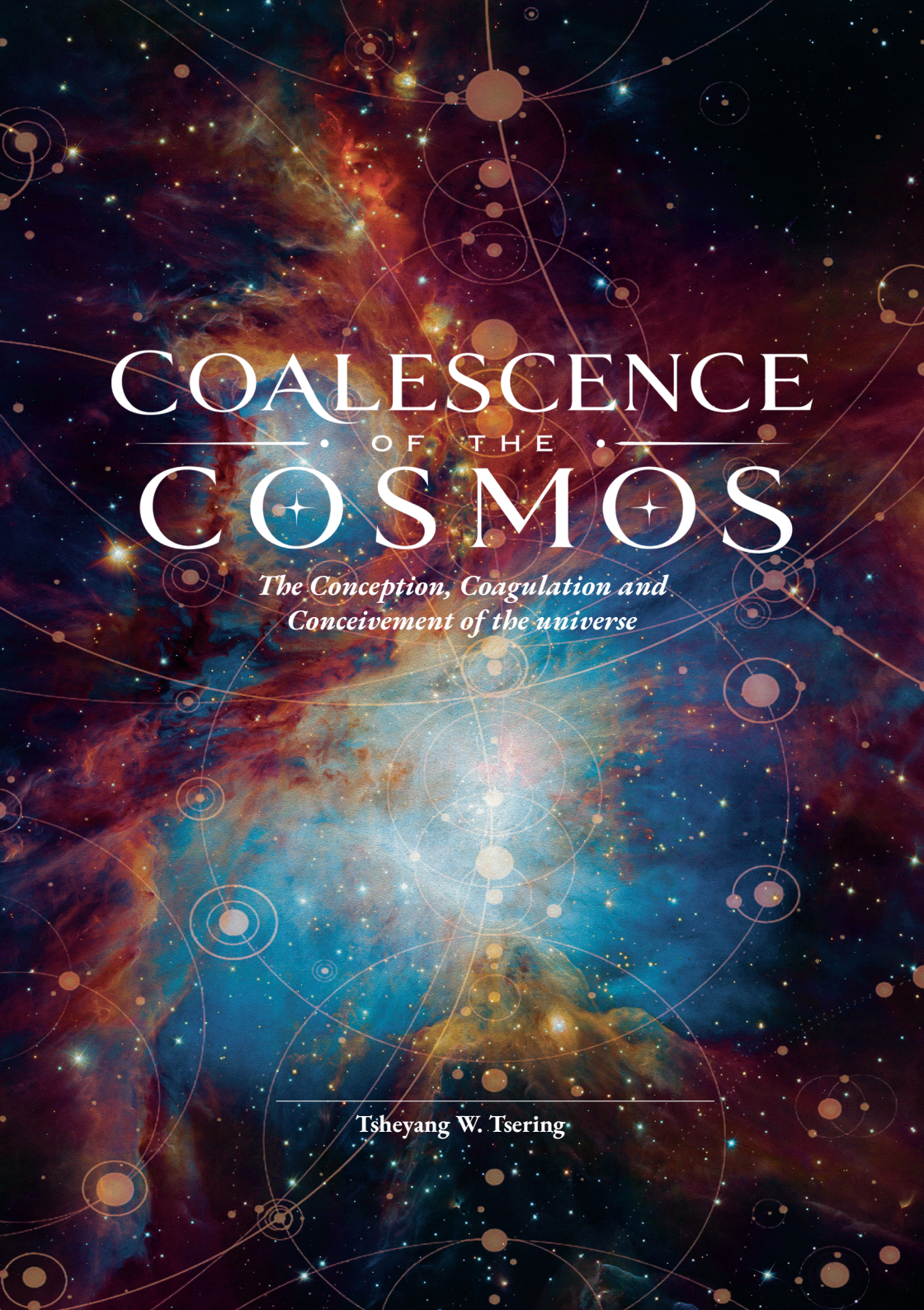


The background of the cover is a vibrant cosmic scene featuring a large, colorful nebula with swirling clouds of gas in shades of blue, orange, and red. Overlaid on this celestial imagery is a complex network of thin, golden lines and circles of varying sizes, resembling a geometric or mathematical diagram. Some of these circles contain small, solid-colored spheres. The overall effect is one of a universe governed by both natural beauty and mathematical precision.

COALESCENCE OF THE COSMOS

*The Conception, Coagulation and
Conceivment of the universe*

Tsheyang W. Tsering

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bhutancornerbooks@gmail.com

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Our not so humble abode

In our cosmos, more stars populate the universe than grains of sand on Earth. An unfathomably vast sea of black that extends past our horizons riddled with tiny dots of light that scatter a galaxy constituted of celestial bodies held together by the natural force of gravity. This is the universe. Larger, more intricate, more elegant and more mystifying than any story that humans could have ever possibly come up with. Movies such as *Interstellar* and *Dune* have helped to open up the door for many to peer into the night sky, but a peer is simply not enough to satiate the hunger of man for knowledge. But if you are unable to learn about your history as a dead star through space from a textbook or countless youtube videos and nonetheless seek a brief introduction to the cosmos and Earth, I offer you this book, *Coalescence of the cosmos*.

Coalescence of the cosmos is my attempt to bring you the brief history of the universe and humanity under the guise of my personal project. Inspired by scientific icons such as Neil DeGrasse Tyson and Richard Dawkins, this book attempts to paint the story of the universe in form of text and engage you in the field of astronomy by retelling the greatest story ever told.

A tale as old as time

The universe is under no obligation to make sense to you

————— *Neil DeGrasse Tyson* —————

Approximately 14 billion years ago, before you were conceived, before the first computer was made, before the first species of humans came into existence, before the first formation of life, all of the energy and mass we see and know about within the known universe, was all compacted into one trillionth the size of one pixel of the device that you are reading this book from. Despite the advancement of technology and science to an almost unimaginably high level during this day and age, the origin of this incomprehensibly small version of our cosmos is still relatively unknown, but what we do know is that when the universe was only 10⁻³⁴ of a second old (or rather young), which to put into perspective is a hundredth of a billionth of a trillionth of a trillionth of a second in age, the cosmos did the only thing it could and inflated and expanded, and it is this event we now term the big bang.

You may know the fastest thing in the universe is light. This would be correct, but when discussing the expansion of the universe, we are not talking about the contents that can be found within the universe itself, but we are talking about the whole. When the universe expands, it does so at a rate faster than light can travel. It was during this phase in the conception of the cosmos that the universe expanded 90 times over, and turned from the size of a pixel in a screen to the size of a golf ball.

After this rapid inflation, the expansion of the universe continued as it

does today but at a slower rate. Now, for an analogy, when you are on a run and are at max speed, it would be understandable that that is when your body would be at its hottest and sweat the most as a consequence of that heat. Now the same sort of logic can be applied to the cosmos, because as the universe expanded to a size bigger than our solar system, the temperature (like your body) quickly dropped to a temperature lower than a trillion degrees kelvin.

This cooling of the universe in essence allowed for me to tell you the tale of the cosmos as it allowed for matter to form, and in a time shorter than it took for you to read this sentence, one second after the big bang to be precise, the universe was filled with particles such as protons, neutrons, electrons, positrons, neutrinos and photons.

And as the universe continued to grow and the temperature kept cooling, the light elements, which are the first three elements on the periodic table were conceived. Protons and neutrons collided with one another to create an assortment of the aforementioned elements, which were the light elements. Protons and neutrons firstly created deuterium, which is an isotope of hydrogen, and those deuterium were the ones that combined with one another to form helium, and also lithium albeit to a lesser degree.

And for the next 380 thousand years, within our continually expanding primordial soup of particles, nothing of note happens, until the temperature of our universe drops under 3,000 degrees kelvin, which is a bit more than half of the sun's temperature at its surface! What might surprise you, is that during that 380 thousand year period, the universe

was actually too hot for light to shine. The residual heat from the big bang lingered and smashed the atoms within our soup of particles with enough force to break them up into opaque soups, of which the constituents were protons, neutrons and electrons.

After the universe had cooled below the 3,000 degree kelvin threshold, matter had cooled enough for the atoms to be able to combine in an era known as the era of recombination. It was during this point in time that the initial flash of light that was created during the big bang was set free, and what may be surprising is that this is detectable even today, under the name of cosmic microwave background radiation. After this point, the cosmos was put into a dark age of sorts as there was no source of light as no stars or bright objects had formed. [2]

And our cosmos came out of this “dark age” of sorts during the age of reionization wherein clumps of gas collapsed to form the stars and galaxies that brighten our horizons today! A billion years later after the time matter first formed, was when matter began to gravitate into the massive concentrations of them which we now name galaxies.

Now when I say that the cosmos is bigger than one could have ever hoped to imagine, there are nearly a hundred billion galaxies, and each galaxy contains their own hundreds of billions of stars. Within the plethora of stars, those that have 10x the mass of our own sun achieve and have sufficient pressure to create elements heavier than the “light” ones and can even create the elements required for life such as carbon and oxygen, which is why the saying, “you are a star!” would technically be correct if it were to use past tense, which is because we are all remnants of dead stars,

which is a fun thought!

And these elements scattered throughout the universe due to the death of stars, so in a sense, new life was formed only due to the death of stars. Thus, it was nine billion years later, at an arbitrary point in the universe, that our source of light and life came to being- the sun. The gas cloud from which the sun originated from contained enough heavy elements to coalesce and create planets both rocky and gaseous.

Now you may also be wondering how stars are made in a bit more detail. They are born in nebulae, which is essentially a birth clinic of sorts for the stars. Nebulas are huge, cold clouds of gas and dust. These clouds shrink under their own gravity and as it undergoes a continuous process of shrinking, these clouds begin to break into clumps, and within each clump begins nuclear reactions due to the density and heat of the clump. And when the clump reaches 10 million degrees, it becomes the same celestial being that lights up our sky. Now, it was from the nebula that the sun was formed that the heavy elements eventually coalesced into the planets, comets and asteroids that make up our solar system.



Figure 1. A picture of a veil nebula courtesy of NASA [20]

As the leftover debris continued to collide with larger bodies of mass, the surfaces of these bodies were constantly molten, which rendered the possibility of life impossible for the first hundred million years. But as time flowed and the leftover debris' supply depleted, the surfaces of these planets cooled down, and as a result the earth formed. And we were incredibly fortunate as the earth was created in a zone as Neil DeGrasse Tyson calls, the "goldilocks zone" [2].

The goldilocks zone is essentially a zone in our solar system where life is possible, as the earth is neither too hot nor too cold. If we were closer to the sun, then all water on earth would evaporate and if we were further away, all our oceans would freeze, and life as we know it today would not be possible!

Scientists believe that the atmosphere that surrounded our primitive earth was most likely made of hydrogen and helium, and that as the crust began to form, volcanic eruptions began to become the norm. And these eruptions were what pumped chemicals such as ammonia and carbon dioxide into the atmosphere. These eruptions also put water vapor into the atmosphere, which condensed and formed what we now know as oceans, where after another long stretch of time, life began to form. During this time, asteroids were still hitting the surface of the earth, and scientists believe that these asteroids were sources of water allowing for life to flourish.

Moving from the 4.5 billion years to a closer point in time, approximately around 2.2 and 2.7 billion years is when the first photosynthesizing bacteria evolved, and these are the bacteria that were

able to change the composition of our atmosphere to what we know today which mostly consists of nitrogen and oxygen. And it is thanks to these bacteria that allowed for the evolution of aerobic life such as you.

The atoms of oxygen that generally form pairs (O_2), also formed threes (O_3) in the stratosphere, which we now know as the ozone layer [1]. This is the same ozone layer that acts as a shield from most of the sun's harmful rays and is talked about everywhere in our modern society, albeit more due to concern than gratitude. And as we fret our own extinction during this modern age, another mass extinction occurred just a mere 65 million years ago, when an incredibly huge asteroid hit what we now know as the Yucatan peninsula (which is within southeastern Mexico). This asteroid wiped off the dinosaurs and more than 70 percent of vegetation on our planet.

As history repeated itself, it was the death of the dominant species (dinosaurs) that allowed us humans to fill the role of the most dominant species of earth. If dinosaurs were to still be alive, then we wouldn't have been able to reach where we currently are. Rather we would simply act as sources of vitamin for T-rex's, that is to say if we were to even survive.

Now we still do not have the whole picture that depicts our tale which is as old as time. What is outside of the observable universe? Is the cosmos and the universe infinitely large, infinitely long, or just an extremely long line? Well, a question many are trying to answer in this day and age and the one I am personally the most interested in is what was before the big bang and if there even was a "before."

We have no evidence for a general scientific consensus to be formed for what preceded the big bang. The science we currently have at this point in time is unable to explore the singularity, or a point of infinite density at the beginning of our beginning. If we were to take that literally, then it would inform us that the universe was once packed into an infinitely small and infinitely dense point, which is unfathomable, which could mean that a new type of physics is required, and the prospect of a new field in science wherein a breakthrough is necessary is immensely intriguing and exciting. This is where string theory (possibly) comes in. It claims to be a model of physics whereby gravities and other forces can be combined at ultrahigh energies, which would mean that it could be able to explain the earliest moments of the universe. However that is another can of worms that will not be tackled as it is simply too complex to be written about in appropriate depth in a book such as this.

But what we do know is that the universe had a beginning and that everything we see, observe, and touch can be traced back to the big bang several billions of years ago. When we try to find out about the past and beginning of the big bang, it is an attempt of self-discovery and learning of our origins, for we are stardust that has passed and have been born from the womb of the universe with the sole purpose of understanding the intricacies and complexities of our cosmos.



Figure 2. 1995 Hubble deep field image depicting the story of the universe [21]

Let there be Light

The Bible shows the way to go to heaven, not the way the heavens go.

———— Galileo Galilei ————

The sun - our main source of life, warmth and light. Essential not only to the human species but to every form of life found on Earth. This dot of light in our skies has obviously played a major part in our survival, but how has this nuclear furnace changed our lives on a cultural level? We all know that without the sun, you wouldn't be reading this book, but other than that, what role has the sun played in society? Well a brief answer would be that the sun has been a source of mystery for as long as we humans have been around. This has lead us on to believe and fabricate tales and theories that attempt to explain the celestial body, from a chariot ridden by the sun god to the sun orbiting the earth in a geocentric model of the universe. But as usual, the story of our sun in society entails much more nuance from the Egyptians to the defamation of Galileo.

To begin the dazzling tales of the sun, I would like to start off by stating the facts we currently know about the sun. The sun is a star that is located in the center of our solar system and is the reason why there is a “solar” system in the first place! The sun is classified as a main sequence star, which in essence means that within the core of the earth, hydrogen atoms are fused together to form helium bonds. And these types of stars constitute approximately 90% of the stars in the universe.

The sun, in the scope of the universe and compared to some of the larger stars known as red giants, is not a very large star but in comparison

to the regular off the shelf star found throughout the universe known as the red dwarfs, is quite a bit larger. And remember in the previous chapter, when it was written that all planets and other bodies of mass in the solar system were made from the leftover nebula that formed the sun? Well that mass certainly does appear in the sun, and just the sun that we see rise and set daily, constituted around 99.8% of all the mass in the solar system. Yes, the sun, within our solar system, contains 99.8% of all the mass, while the other 0.2% of the solar system consists of all the planets, asteroids, meteors and satellites that circle the sun. The sun also has a diameter 110 times the diameter of Earth with a whopping diameter of 1.4 million kilometers, and to put this into perspective, this would mean that around one million earths would be able to fit inside the volume of the sun. Now, another thing you may not have ever thought about is that the sun also orbits and is not stuck in space time till the end of time The sun, does not orbit the earth, which was a very big blow to the ego of the earth-chauvinists, but rather it orbits the Milky Way. The sun, along with all its planets travel across the Milky Way, where they take approximately 225 - 250 million years to complete one full revolution around the center of the galaxy.

Now, circling back to the nuclear fusions in the core of the sun, the core of the sun loses some of its hydrogen fuel, which causes the sun to contract and heat up, and this change to the core is what causes the core to expand and as a result fuse more hydrogen atoms to form helium atoms. After billions of years, the fusion reaction causes the sun to increase its energy output, until one day when the core will run out of the hydrogen fuel that provides energy to sustain our life on Earth. This again would cause the contraction and the heating up of the sun's core, igniting helium fusion during which the outer layers of the sun would

continually expand, until it becomes a red giant. Although this is still a debated topic in the scientific community, it is thought that when the sun does expand, we all would be toasted, alongside Mercury and Venus. But once the sun does complete its red giant phase, the sun will retain its mass, but will collapse and will have a volume similar to that of Earths (That would be one dense object, but still not as dense as the neutron star). And if we were to personify the sun to a Human, it would currently be in his 30's to 40's because he would currently be midway through his life and is a yellow dwarf star. And in a hypothetical sense, to create some anxiety in the back of your mind, if there was a higher and divine being that created the universe, and he just plucked the sun out of our solar system, then you would assume that we would be able to tell instantly, but the truth is, we would only be in shock and horror eight minutes after the deed had been done. Eight minutes and twenty seconds to be precise. That is because the fastest thing (that we know of) within the universe is light, and since light caps out at approximately 300,000Km per second and the distance between the earth and the sun is 150 million Km, we would only find out about the sun conundrum 8:20 minutes after it had begun. Now the last fun fact about the sun before we delve into the history of the sun in our history, in a societal sense, is the etymology of the word "Sun." The word "sun" originates from the old english word "sunne" which itself is derived from the old proto-German word "sunnōn."

Now we shine a light on the cultural impact of the sun in society. Before the invention of the light bulb and discovery of electrical energy, human civilization relied on the sun as the primary source of light, which is why as a species we have evolved to work during the day and sleep at night. Our ancestors' reliance on the sun led there to be an incredible

importance in the reverence and worshipping of the sun. Several of our most famous landmarks today were created in honor of the Sun. For instance, the Stonehenge landmark that can be found in the UK has been shown to have a connection to archaeoastronomy. The Stonehenge has been shown to align in the direction of the sunrise during the summer solstice and the sunset during the winter solstice.

Another famous sighting nowadays are the pyramids in Egypt. For centuries, there has been constant debate on how the Egyptians were able to pull off a feat as large as they did when they built the pyramids so precisely, but recently engineers discovered that the Egyptians could have used the sun, specifically on the fall equinox to precisely build the pyramid to 1/15 of a degree with the help of tools such as gnomon, which allows one to track the movement of the sun.

The Mayans also worshipped the Sun. Yes, the same Mayans that had “predicted” our world would end in the year 2012. NASA writes that “The Mayan culture in Mexico focused on astronomical almanacs that rigidly controlled behavior and religious ceremony. The Pyramid of Kukúlcan marks the two equinoxes where a snake appears to crawl down the temple.”

Throughout our past, humans have had a lot of ego (which we still do) and believed that everything that was happening was due to their own doing, which is why there were several mythologies in human history wherein the sun was a supernatural force or a divine being that required sacrifices in not only the form of domesticated animals but also humans. In ancient Greek, Roman, Mayan and Egyptian cultures, when the rain was

plentiful and crops were abundant, the gods were happy, whenever there were droughts, the higher beings were angry. When there was an eclipse the god was incredibly displeased, and it was only around a few thousand years ago that we figured out that most of these occurrences could be explained through scientific deduction and that we as humans did not and cannot control everything. But to give credit to our ancestors, some of the myths are not all baseless. For instance, the ancient Greeks and Romans believed that the god Apollo, god of the sun, also held control of the domains of music and healing, which has proven some merit. This is because during the 1880's, scientists discovered that the UV that travelled through the vacuum of space from the sun through our atmosphere to the Earth's surface was able to kill the bacteria that caused tuberculosis.

Despite evidence after evidence pushing us to the idea that we were not the protagonists of the universe and that not everything had to be built around us humans. We still believed that the sun orbited the Earth and that we were incredibly important in the larger scale of the universe (Some of us still believe we are, but that will be criticized in the later chapter "Chauvinism of man"). And that remained true until the time of Galileo, when another blow was dealt to the fragile (or rather stubborn) ego of geocentric apologists.

Now, the story of Galileo is similar to that of a Shakespearean tragedy. He was born on the fifteenth of February nearby Pisa. His father was a musician, and he originally chose to study medicine, but later changed to philosophy and maths when studying at the university of Pisa. In 1609, Galileo was a professor of mathematics at the University of Pisa when he heard of the invention of the telescope credited to Hans

Lipperhey. Without a visual representation of this new invention, Galileo constructed a telescope vastly superior to its predecessors, and it was with this telescope that Galileo discovered the landscapes on the moon, four of the largest moons orbiting Jupiter and the phases of Venus. Everyone believed his discoveries, until 1614, when he was accused of heresy for supporting the Copernican theory of heliocentrism, which stated that the Earth orbited the sun rather than the sun orbiting the Earth. Two years later, he was forbidden from advocating for “lies” within the church. Then later in 1632, when he published his book “Dialogue Concerning The Two Chief World Systems”, Galileo was summoned to appear before the Inquisition of Rome, where he would receive a punishment of lifetime imprisonment, which was later reduced to permanent house arrest. And yet, despite going blind, he wrote “Discourses Concerning Two New Sciences” in 1638 and would later die in 1642 on the 8th of January [3].

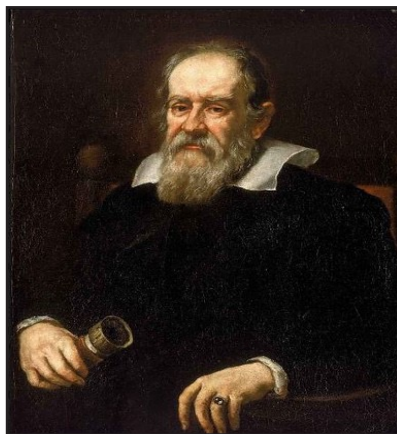


Figure 3. Portrait of Galileo Galilei [22]

Now, in our modern age, there is irrefutable scientific evidence that the Helio-centric model of our solar system is the correct one. This

tale sets a precedent that no matter how one tries to suppress “lies”, scientific knowledge prevails over the passage of time. But to end off this chapter on a less solemn note, another connection that our lives now have to the solar system can be found in the way we communicate the days of the week. The etymology of the days of the week are derived from the classical planets found within Hellenistic astronomy. The first two days of the week, Sunday and Monday are obvious where they are derived from (the Sun and Moon). Tuesday is related to the Germanic god of war. English is a Germanic language, which led to the substitution of the day’s names for equivalent German gods. The German god of war is Tiu, hence the name Tuesday. The original god Wednesday was named after Hermes or Mercury (in Latin), which was later substituted with the Germanic god Woden, which is why we now know the name to be Wednesday. Thursday was the day of Jupiter, the god of thunder and lightning, whose equivalent in Norse mythology is Thor, which led the day to be termed Thor’s day, and now Thursday. Friday was originally termed after the goddess of love and affection, Venus, whose Norse counterpart is Frigg and also possibly Fria, who were both goddesses of love which led us to the beloved Friday. Now Saturday is another simple one, as it is based on the Roman god, Saturn, which is why the day is Saturday.



Figure 4. Carracci’s portrayal of the triumph of Bacchus and Ariadne in 1523 [23]

Observe the invisible

“Man must rise above the Earth—to the top of the atmosphere and beyond—for only thus will he fully understand the world in which he lives.”

————— Socrates —————

First, before I describe black holes for how we understand them today, I would like to pose the question, how does one observe or discover a black hole, if (almost) no type of light can escape the event horizon of a black hole? Think about it, almost everything on Earth we study can be observed and seen with the help of tools such as microscopes. But the reason we are able to do so is because of the light that the object reflects, which hits our retinas, creating the images that you see. But now in the case of black holes, almost no light is able to escape the event horizon, which means that it is a near perfect black body. The only reason that a black hole is not a perfectly dark and black body is due to it not being able to absorb the photons with wavelengths that exceed the size of the black hole. So, how do we know that black holes do exist and aren't just a hoax used for science fiction movies such as interstellar? Well, the answer to that is that organizations such as NASA point their telescope to the surrounding environments around the black hole. The material that is close to the event horizon (I will explain what an event horizon is later) gets heated to millions of degrees when it gets sucked into the black hole, which causes the object to emit x-ray. We can also observe the impact of an invisible gravitational force that tugs and pulls on stars and other celestial bodies.

Now that the hypothetical is out of the way, I hope that I

have succeeded in sucking (pun intended) you into the vast and rather unknown world of black holes. I'd like to begin talking about how we, insignificant human beings, discovered black holes and have spent decades trying to decipher this exotic object within our cosmos. Most people often date the discovery of the black hole to the 1910's, around the same time period that saw Einstein set up the foundations for the future of physics in the form of general relativity, but the original discovery of the black hole actually occurred earlier during the 18th century. A humble English rector who went under the name of John Michell was so ahead of his time that it took a century for his ideas to be reinvented and accepted in the scientific community. Born in 1724, Michell attended Cambridge University where he would later teach for a period of time before moving to Thornhill to become rector there. Michell was an incredibly accomplished scientist who was elected into the Royal Society in 1760 for his contributions to the field of physics and geology. But arguably his most incredible finding was his inception of the idea that black holes existed in our cosmos. In the year 1783, Michell was considering a hypothetical method wherein he tried to determine the mass of a star. Michell utilized Newton's corpuscular theory of light which stated that light was composed of small little particles (photons), to hypothesize that these photons that emerged from the surface of stars would be slowed due to the gravitational pull of the star. And from this deduction, he wondered if it would be possible to calculate the mass of the star by measuring the reduction in speed of light for any given star. He understood that an "escape velocity" which is a certain critical velocity required by an object to surpass so as to escape the gravitational pull of the star, depended on the size and mass of the star. And continuing on this hypothetical, he wondered what would have happened if the escape velocity required to escape the gravitational pull of

the star exceeded the speed of light. Michell realized that the light would be pulled back to the surface, unable to escape. With the help of Ole Roemer who had discovered the speed of light in the prior century, he worked out that the escape velocity for a star would exceed the speed of light when the mass of the star was 500 times that of our suns assuming that the average density remained the same. He then concluded that because the light would not be able to escape such a body in space, that the object would be invisible to the outer world [5].

This was a breakthrough so momentous and ahead of its time that it was disregarded by the scientific community at the time. Then, over 100 years later in 1916, after the publication of Einsteins' work, Karl Schwarzschild solved Einstein's equations for the circumstances surrounding a black hole. He envisioned a black hole as a spherical volume of space that was warped and was circulated by concentrated mass which was invisible to the outside world. And that is the brief history of black holes till their acceptance in our scientific community in the year, but over the past 100 years, several new details of the black hole have been worked out, but before we get there, we need to understand what a black hole is and what parts of the black hole make up this invisible celestial object in our cosmos. Oh, and if you were wondering if Michell's original hypothesis was correct, that one could calculate the mass of a star with the help of the reduction in speed, he was incorrect. This is because in Einstein's theory of relativity, light moves at a constant speed throughout space regardless of the local gravitational strength.

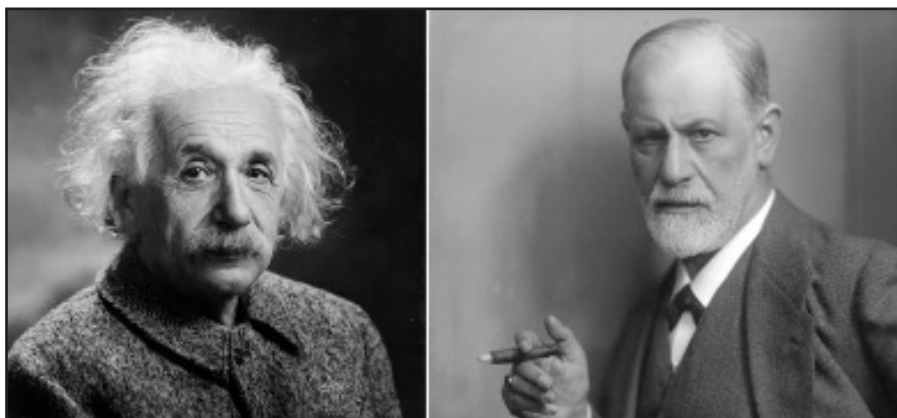


Figure 5. B&W images of Albert Einstein and Karl Schwarzschild [25]

So, what is this hole of blackness I have been talking about this whole chapter? Well, A black hole is essentially a place in space wherein the gravity is so strong that not even light is able to escape its reach. The gravity is this strong due to matter being squeezed into an infinitely small space. A stellar mass black hole (a variation of a black hole) can likely form in the matter of seconds after the collapse of a massive star. These types of black holes can also be made through the merging of two dense stellar remnants known as neutron stars. Black holes can be formed in all types of sizes, ranging from the size of an atom to the ones in the middle of galaxies known as supermassive black holes. To put into perspective how dense these black holes are, the black holes the size of atoms contain the mass of a large mountain, so one can imagine (or rather cannot fathom) the true mass of the supermassive black holes. Black holes are classified by their mass, so the black hole that I previously called “Stellar mass black hole” falls under the stellar classification of black holes. Stellar black holes can have mass up to 20x more than our sun, and there are several of these stellar black holes within our galaxy, the Milky Way. The largest blackholes

which you could have probably guessed are the supermassive black holes. These black holes can have the mass of more than 1 million suns put together. Scientists have recently found evidence that in the center of each galaxy there is one of these supermassive galaxies. The one that can be found in the center of our galaxy is known as Sagittarius A. This black hole contains the mass of 4 million suns put together and would fit into a ball that would fit a few million earths, which is a testament to the density of these black holes.

Another question you may have is how these black holes are created in the first place? Like what causes all of this matter to form a black hole? Well, stellar black holes in particular are said to be created when the center of an incredibly large star collapses into itself. And this collapsing is what causes a supernova to occur. A supernova is the massive explosion of a dying star which dies due to it exhausting all of its fuel (don't worry, our sun does not have enough mass to supernova). Supernovas are also responsible for the spreading of star remnants across the universe. For the formation of the supermassive black holes, astronomers are still unsure of how these black holes were formed, but scientists think that the supermassive black holes were formed at the same time the galaxy they reside in.

Now, onto the different parts of the black hole. How many major parts are there to a black hole? Over a hundred? Over one thousand? One hundred thousand? Well, the answer may surprise you. You have already heard of 50 percent of the constituents that make up a black hole. That 50% is the event horizon. From that information, you may have realized that the black hole, which has been creating issues for physicists and

astronomers for decades, is made up of just two major parts. The first of which is the event horizon. The event horizon is essentially the closest thing to a surface a black hole has. The event horizon however, is not something you can touch and feel, but rather an invisible bubble in space. It is the outer limits of the black hole. If you were to ever cross this event horizon and go into the “bubble” of the black hole, there is no way out (This is still a hotly debated topic between physicists studying quantum mechanics and general relativity). We are unable to see inside the event horizon, for obvious reasons (no light gets out) but with the help of the language of the universe (math), we are able to get an idea of what it could possibly be like. If you were to fall into the event horizon of a black hole, you would be spaghettified. No, seriously. That is the scientific term for the vertical stretching and horizontal compression of objects into long thin shapes. So, I wouldn't rate black holes as a good vacation spot if you ever wanted to go there [6].

But what is at the center of all of this (pun intended)? At the center of the black hole, the other major part that constitutes the black hole is the singularity. The heart, the soul of the black hole. All of your spaghettified body (or what's left of it) would eventually get crushed into this singularity point. The singularity is the tiny point wherein all the mass of a black hole is contained. How does the mass of a mountain fit into the singularity of a black hole the size of an atom is still a mystery. And to find out how it works, scientists will need to find a theory that combines the theory of quantum mechanics (which deals with the small) and general relativity (which deals with the large) into a single theory. A theory of everything. The god equation. Similar to how $E = mc^2$ was able to unlock the secrets of the stars by uniting energy and mass, scientists are currently

striving to find an equation that would explain our reality and everything within it. A popular theory that could possibly be the answer to everything is string theory, which proposes that our universe is fundamentally composed of one dimensional strings rather than the more conventional way of thinking, which is that particles make up our universe. But string theory is still unable to be tested through experiments, which is why there is a huge divide in the scientific community on the topic of string theory.

However, today we can assert for certain that black holes do exist and that humans have come a long way since their disbelief of John Michell. We have even been able to take a picture of the black hole. This feat required the Event horizon team, who took the picture, to create a virtual telescope bigger than our globe and pioneer several new technologies in radio astronomy. With the team consisting of over 200 scientists in over 20 countries using eight of the world's most sensitive radio telescopes, synchronized atom clocks, two custom supercomputers, computational imaging and 10 years of work, were able to visualize the light fringed shadow that was cast by M87*, a supermassive black hole that is centered in the galaxy Messier 87, which is a galaxy in the Virgo constellation [7].



Figure 6. First image of a black hole captured by humans [24].

Humanity's first image of a black hole isn't sharp, nor beautiful. It isn't like the illustrations that are shown in the movie *Interstellar*. It's better. The image that we humans see and observe as the first real picture of a black hole is composed of bits and scraps of light that travel through the universe which have been collected by us humans, and then compiled in a supercomputer. It is physical proof of how far humanity has come, not only in the past 1000 years, but even the past 100 years and has helped us understand the universe better. As Stephen Hawking once said, "The progress of the human race in understanding the universe has established a small corner of order in an increasingly disordered universe" [8].

Chauvinism of man

We are like butterflies who flutter for a day and think it is forever.

————— Carl Sagan —————

We as humans tend to believe that we are at the center of the universe whether it be consciously or unconsciously. The concept is that the universe was created by a higher divine being for us humans who have occupied less than a fraction of the universe for the most recent 0.002% of the universe's age [9]. This chauvinist mindset has (whether it be intentional or not) even found its way into our everyday language when we say "The universe hates me" or "Why is the world against me." The intrinsic bias to believe that one is all important is often humbled when learning more about astronomy. But why believe me, rather it'd be better to read what Carl Sagan writes in the *Pale Blue Dot*:

"Ann Druyan suggests an experiment: Look back again at the pale blue dot of the preceding chapter. Take a good long look at it. Stare at the dot for any length of time and then try to convince yourself that God created the whole Universe for one of the 10 million or so species of life that inhabit that speck of dust. Now take it a step further: Imagine that everything was made just for a single shade of that species, or gender, or ethnic or religious subdivision. If this doesn't strike you as unlikely, pick another dot. Imagine it to be inhabited by a different form of intelligent life. They, too, cherish the notion of a God who has created everything for their benefit. How seriously do you take their claim?" [10].

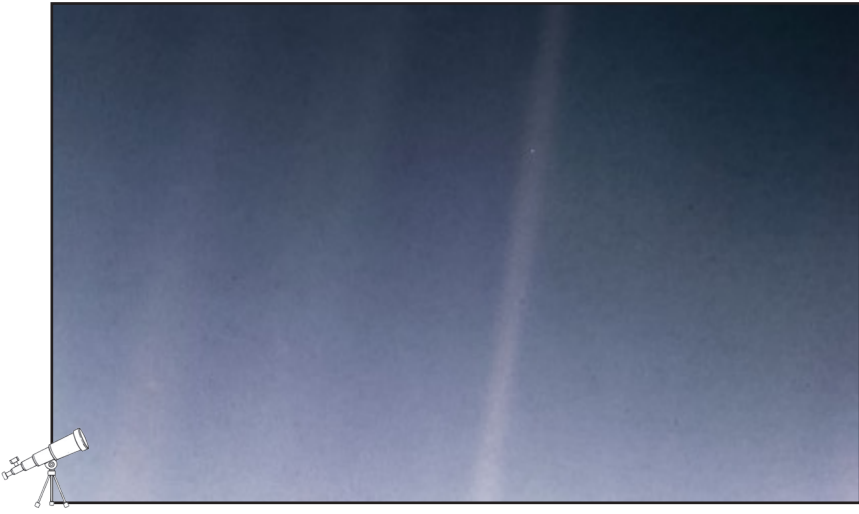


Figure 7. Voyager 1's picture of the Earth. That vibrant dot is everything you have ever known[26]

Our ancestors walked on the same land under the same blanket of sky that lay overhead. When we look overhead, we see the sun, moon and planets all rising from the east and setting in the west, as if working in perfect synchrony for us humans to decipher the season and time, which allowed us to attain food and shelter. Surely it was no accident that the heavenly bodies that “orbited around us” helped us survive, what other purpose or who else would these heavenly bodies be working in perfect unison for? This must mean that we are at the center of the universe, rulers of sorts, with the sun and moon fawning over us and providing us with sustenance. This observation and conclusion drawn of the universe makes it seem perfectly reasonable to assume that the Earth would be at the center of the universe as it seemingly looks to be crafted for us humans in particular because why else would it be how it is? Well, it is this assumption made of the skies that had caused our society to believe in the geocentric

model of the universe for centuries. And yet, despite the constant belief of humans, from kings to philosophers to poets that the heavens orbited Earth, it continued to orbit the sun rather than the contrary.

Throughout the history of humanity, we have lacked creativity when trying to familiarize ourselves with the vast universe. In the West, Heaven is a cloudy and fluffy space with angels and gods while hell a burning fiery mess with human-like punishments. Throughout many religions, the governing bodies are constituted of gods and devils that operate in similar manner to that of humans, with a class system for the heavens and the hells and as a consequence the cosmos. But why is it that humans want to believe that the universe was made solely for us? We can't know for sure (as of yet), but if I were to guess, it would be that it appeals to our vanity and to the innate human ego. As Demosthenes once said, "What a man desires, he also imagines to be true." Which is why most often people find it annoying when scientists remind them that they are "unimportant and that there is nothing special about every one of us." Why can't scientists simply find a way to make us feel special? Why can't they find a reason for us to believe that we are unique and belonging within the universe [2]? A question that is on the other end of the spectrum is what does religion and philosophy offer to us humans? Do we want to hear fables to make us feel at ease or the actual inner workings of what surrounds us and how the cosmos goes?

In contrast to older religions that present humans as the end goal, the heart of the cosmos, while modern sciences tend to portray humans as an accident. We are a result of the cosmos, but do not contribute to why the cosmos is. As Carl Sagan writes, "science is spiritually corrosive,

burning away ancient authorities and traditions. It cannot really co-exist with anything.” . . . “Science, quietly and inexplicitly, is talking us into abandoning ourselves, our true selves.” It reveals “the mute, alien spectacle of nature.” . . . “Human beings cannot live with such a revelation. The only morality left is that of the consoling lie.” Anything is better than grappling with the unbearable burden of being tiny” [10].

We lack a societal consensus on what our purpose in the universe is. No agreement on why we are here, how we came to be nor the long term goal for our species (other than survival). And when times are rough for humans, it is often reassuring to hear that God has a plan for all of us and that everything happens for a reason. But if what we seek when exploring the heavens is to find a deeper understanding of our place within the universe rather than shallow comfort, we can truly understand the questions that have plagued our species. Rather than worry that we may be truly insignificant in the grander scheme of things, we can view the universe for what it truly is, a vast and incredible space (pun intended) that makes our ancient anthropocentric model of the universe pale in comparison.

Religions in essence, can be understood to have arisen due to the unnerving phenomena of nature such as lightning and volcanoes that scared our ancestors of the time. Religion was an attempt to rationalize rather than understand the confusing aspects of nature. And as time progressed and the scientific revolution allowed for us to understand the “magic [10-11]” behind mother nature, it allowed for us to mitigate the harm of natural disasters such as droughts, and in this sense, science brought hope.

A popular story within the bible is about the Garden of Eden. A garden custom tailored to fit the needs of us humans, with only the tree of knowledge being forbidden within the boundaries of the garden. We as a species were meant to be kept ignorant, but due to curiosity and our hunger for knowledge, all of the troubles that entail being a human arose. And some now mourn the lost world, but I personally find this story to be shockingly similar to our society in reality. When Galileo was placed within the Garden of Eden (our society), he was curious and sought knowledge on how the heavens go and when he bit into the apple of knowledge and wrote about the helio-centric model of the solar system, he was condemned by the “angels” and forever exiled, the former gardener now in exile and wanderer. Ironically, there is now irrefutable scientific evidence that the heliocentric model of the universe is correct, which is why I think that we would not have been happy in the Garden of Eden. We would not have happily stayed ignorant.



Figure 8. The Garden of Eden by Wenzel Peter [27]

Thus, in the end, the importance of our lives are determined by our own wisdom and courage. We determine the importance of a life, and despite our desire for there to be an architect that made this universe solely for us, knowledge is still more desirable than ignorance. Astronomy puts all of our problems and achievements in the scope of the universe and humbles us. Everything that you have learnt about in history has to do with the Earth. Every emperor, every war, every death, every hero. As Carl Sagan once wrote, “The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emperors so that, in glory and triumph, they could become momentary masters of a fraction of a dot” [10].

Falsehoods of society

The fault, dear Brutus, is not in our stars, But in ourselves

————— *William Shakespeare* —————

For a society so dependent on science and its marvels, one would expect the people who constitute society to believe in science, but to the dismay of many this is not the case. Several pseudosciences have plagued society and have influenced generations that are susceptible to manipulation. This topic may seem incredibly detached from the previous chapters that have discussed topics that are studied by scholars who dedicate themselves to the sciences, but I think that it would be beneficial to also point out the aspects of “science” that should be scrutinized more in the public eye.

Astrology and fortune telling

Pseudosciences have been around much longer within our society than science itself in the form of astrology and fortune telling [18]. In Greece for instance, there was an Oracle which could be found in Delphi. This was a religious sanctuary that was sacred to the god Apollo and within this sanctuary one would find the priestess Pythia. Pythia would answer questions asked to her by visitors. The answering of these questions entailed a whole ritual which began from the purification and drinking of holy water to the sacrificing of an animal, which was usually a goat. We still do not understand the whole process of how the Oracle was able to predict the future as the secret technique remained true to its secrecy and was kept under wraps. But most ancient historians theorize that she read the internal organs of the animal that was sacrificed to predict the future and answer the question. Now, how do the organs of a goat help to predict the future? Your guess is as good as mine. But despite the importance of the oracle being reduced when Christianity was introduced to the Roman Empire, the act of seeking guidance from a higher being or a divine power has withstood the test of time [19].



Figure 9. Only surviving image of the Delphic Pythia and mystical king Aegus [29]

The Oracle of our times are fortune tellers and the crystal ball readers. Despite the practice of fortune telling being referred to as a scam and frowned upon, a significant number of people still put their hopes in the act of looking into a crystal ball and hoping for good fortune. And now, with the rise of the internet, it has helped to further the teachings of pseudosciences through YouTube channels dedicated to tarot readings and astrology Instagram pages that are supposed to govern the daily activities of an individual. While many believe that astrology is just harmless fun and does not harm individuals, there are experts that hold contradictory beliefs. Astrology has been discredited for centuries, and yet still contributes to the zeitgeist of today. And despite the popularity, there has been no evidence that explains the mechanics behind how the alignments of cosmic bodies affect us humans on a daily basis. Furthermore, our perspective and gauge of time is solely based on cultural constructs rather than a more cosmological basis, which is the basis of astrology.

Research by the National Science Foundation has shown that over 40% of Americans believe that astrology is a real science [12]. And no, this statistic was not inflated by the confusion between astrology and astronomy. That statistically means that more than every third American you talk to believes that astrology is based in reality. The demographic that mostly contributed to this demoralizing statistic is due to the younger generation ranging from 18 - 24 years of age. Other research has shown that women are more drawn to astrology than men [13]. Now you may be wondering why this may be a problem? Well, sociologist of York University Julia Hemphill argues, “Astrology is an unempirical epistemology that’s peddled to women as a way of understanding themselves and the world,” she says. “All you have to do is open a ‘women’s magazine’, and you’ll

inevitably see at least one or two pages devoted to astrology” and this could lead to women being deterred from learning actual sciences, which has been a large issue in society (Male chauvinism) [14]. Another reason why astrology should be discouraged is due to it causing uncritical thinking. Astronomer Phil Plait writes:

“The more we teach people to simply accept anecdotal stories, hearsay, cherry-picked data (picking out what supports your claims but ignoring what doesn’t), and, frankly, out-and-out lies, the harder it gets for people to think clearly. If you cannot think clearly, you cannot function as a human being. I cannot stress this enough. Uncritical thinking is tearing this world to pieces, and while astrology may not be at the heart of that, it has its role” [14].

In a conceptual sense, it also promotes determinism as people have this incorrect belief that everything is predetermined and one cannot do anything due to it already being “written in stone.” But this could also be the reason why astrology has survived the test of time, to make us feel connected to the cosmos and gives us a sense of relief that our daily routine has a higher significance than what we are truly carrying out, which can be contrasted to the cosmic perspective in the prior chapter.

Flat Earth

Sigh, writing the words flat and Earth in close proximity is one that makes me worried for the future of our society. Why are we in the 21st century questioning the shape of the Earth when even the Greeks knew that it wasn't flat in 500 B.C? I honestly believe that it is purely for attention and to be a contrarian, but those are just my two cents. But I would like to recount the tale of flat Earth within modern society because everything deserves a chance, right (not this topic but we will go with it)?

The notion about the flatness of the Earth began with Samuel Birley Rowbotham who lived during the mid 1800's. Rowbotham who went under the pseudonym "Parallax" employed his method of "Zetetic astronomy" to conduct the Bedford Level experiment. The Bedford Level experiment is essentially a series of observations that was carried out over a 6 mile long river to measure the curvature of the Earth. Rowbotham hypothesized that he should no longer be able to see the object after 6 miles due to the curvature of the Earth but observed that that was not the case [15]. Hmm, what's wrong with this experiment? It seems logical doesn't it? Is the Earth really flat? Well, the reason why this experiment does not prove the flatness of the Earth is due to it not accounting for how the natural world operates. Atmospheric refractions produce the results that were observed in Rowbotham's case. Due to the density of air, Earth's atmosphere decreases with height above the Earth's surface. Therefore light rays that travel horizontally bend downward, which causes line of sight to curve [16]. And because the measurement was so close to the ground, the downward curve of light matched the curvature of the Earth, cancelling one another out, which is why the Earth looked "flat" within

this experiment.

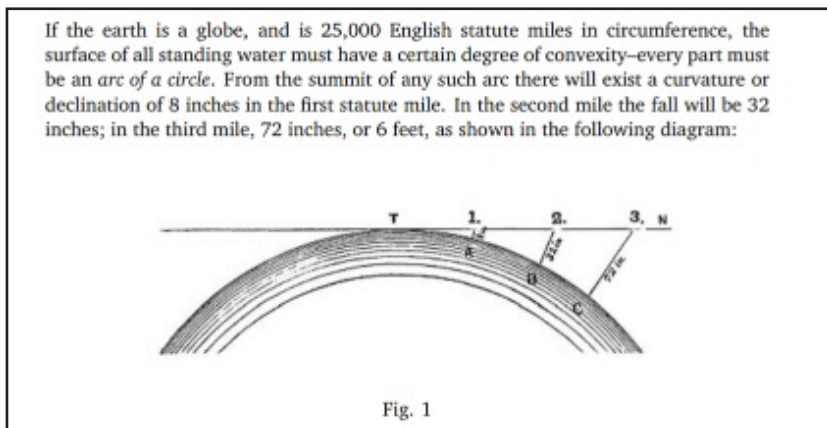


Figure 10. *Writing of Rowbotham in Zetetic Astronomy: Earth is not a globe* [28]

I have spent quite a bit of time watching videos on flat Earthers and the conventions they head to, and most of the flat Earthers state that they fell into this rabbit hole through their own research on YouTube, so it is in my best interest to warn you to think on a deeper level than the surface. Firstly, if you are sceptical about something similar to the flat Earth, think about what benefits governments across the world as a collective would reap from lying about the shape of the Earth. I also recommend finding sources of information other than YouTube as it may not be the most reliable source of information. Perhaps use it as a jump pad of sorts before reading more academic papers. And after observing the wild creatures that are flat Earthers, I believe that the flat Earth movement is a reaction of sorts to the abstract nature of science as it is now. Most methods of science are now theoretical, which may be hard for most to accept as humans because we as a species have evolved for over 2 million

years with the help of senses such as touch and sight. And with the rapid growth of science within the past few centuries, one may feel unease in trusting something they cannot feel nor touch, which is the “science” of today. Thus, flat Earth in a sense could be interpreted to mean less about the shape of the Earth, but rather be pushing a broader message, a message that calls for reductionism within science so that we use our senses once again to make conclusions on our reality [17].

And this is it. The end of the book, the end of our rather short time together as narrator and reader. But before you leave, I would like for you to reflect on us humans and our place in the universe. We humans have come as far as we have due to our innate curiosity to want to know more. More about our lands, our oceans and our skies. And if it were not for our curiosity, we would still be stuck in caves running from predators worrying for our lives. I would like to encourage you to ask your own questions about what we as humans have learnt in our brief time in the cosmos in tandem with asking what we do not know about the universe and the pale blue dot we live on, for as Claude Levi-Strauss once said, “The scientist is not a person who gives the right answers, he is one who asks the right questions.”

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Approximately 14 billion years ago, before you were conceived, before the first computer was made, before the first species of humans came into existence and before the first forms of life emerged, all of the energy and matter we see and know within the observable universe was compacted into a space smaller than one pixel on the device you are reading this book on.

Despite the advancement of technology and science to an almost unimaginable level, the origin of this incomprehensibly small version of our cosmos remains one of the greatest mysteries in science. What we do know is that when the universe was only 10^{-34} of a second old, which to put into perspective is a hundredth of a billionth of a trillionth of a trillionth of a second, the cosmos did the only thing it could: it expanded. This event is what we now call the Big Bang.

About the Author

Tsheyang W. Tsering wrote *Coalescence of the Cosmos* at the age of 14. Fascinated by the origins of the universe and humanity's place within it, he developed a keen interest in astronomy and cosmology. Through this book, he shares his fascination with the cosmos and invites readers to explore some of humanity's biggest questions.

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