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A Brief History of the Universe

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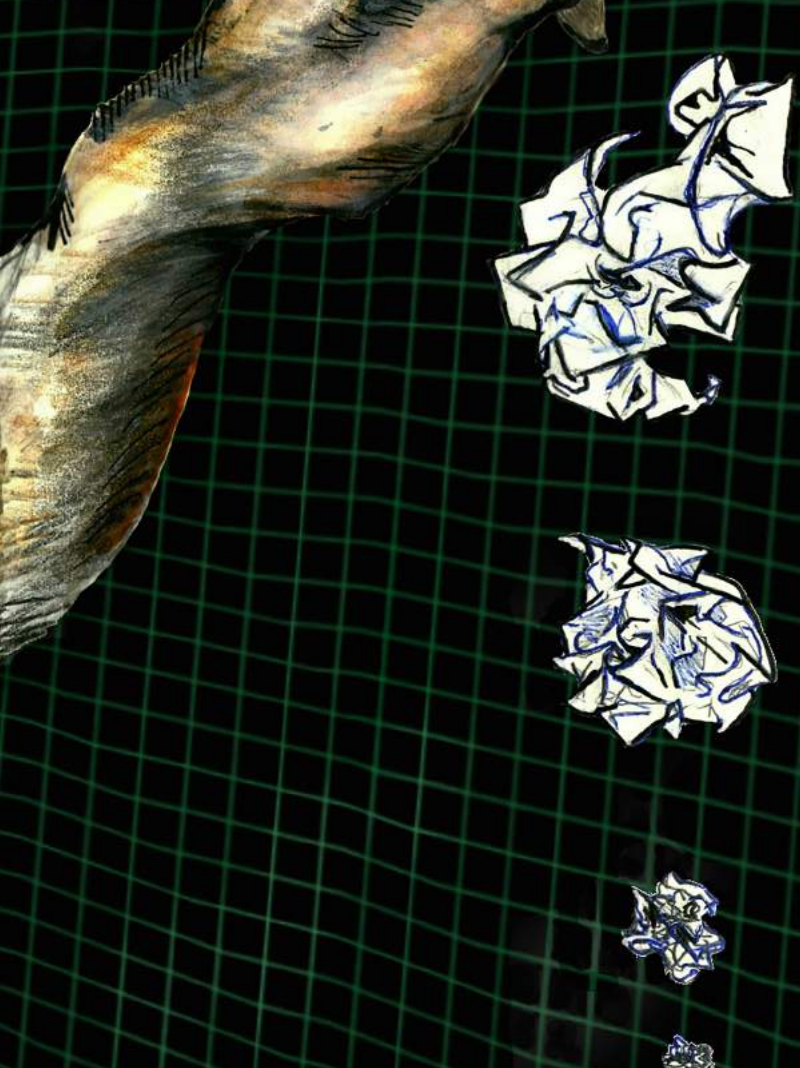


The Big Bang

13.8 Billion Years Ago

At the beginning of time,13.8 billion years ago, all the matter and energy of the known universe was contained within an infinitesimal fraction of space. One trillionth of the size of the point of a pin, this object did not occupy a location in the universe, but rather was the entirety of the universe. It was not a where, but a when. That is, until it exploded outward with monumental force. From zero to 10-43 seconds after the Big Bang, conditions were so extreme that the forces that govern the universe—gravity, electromagnetism, strong interaction, and weak interaction—were unified and melded into one. This is the known as the Planck Epoch, the very first moment of the universe.

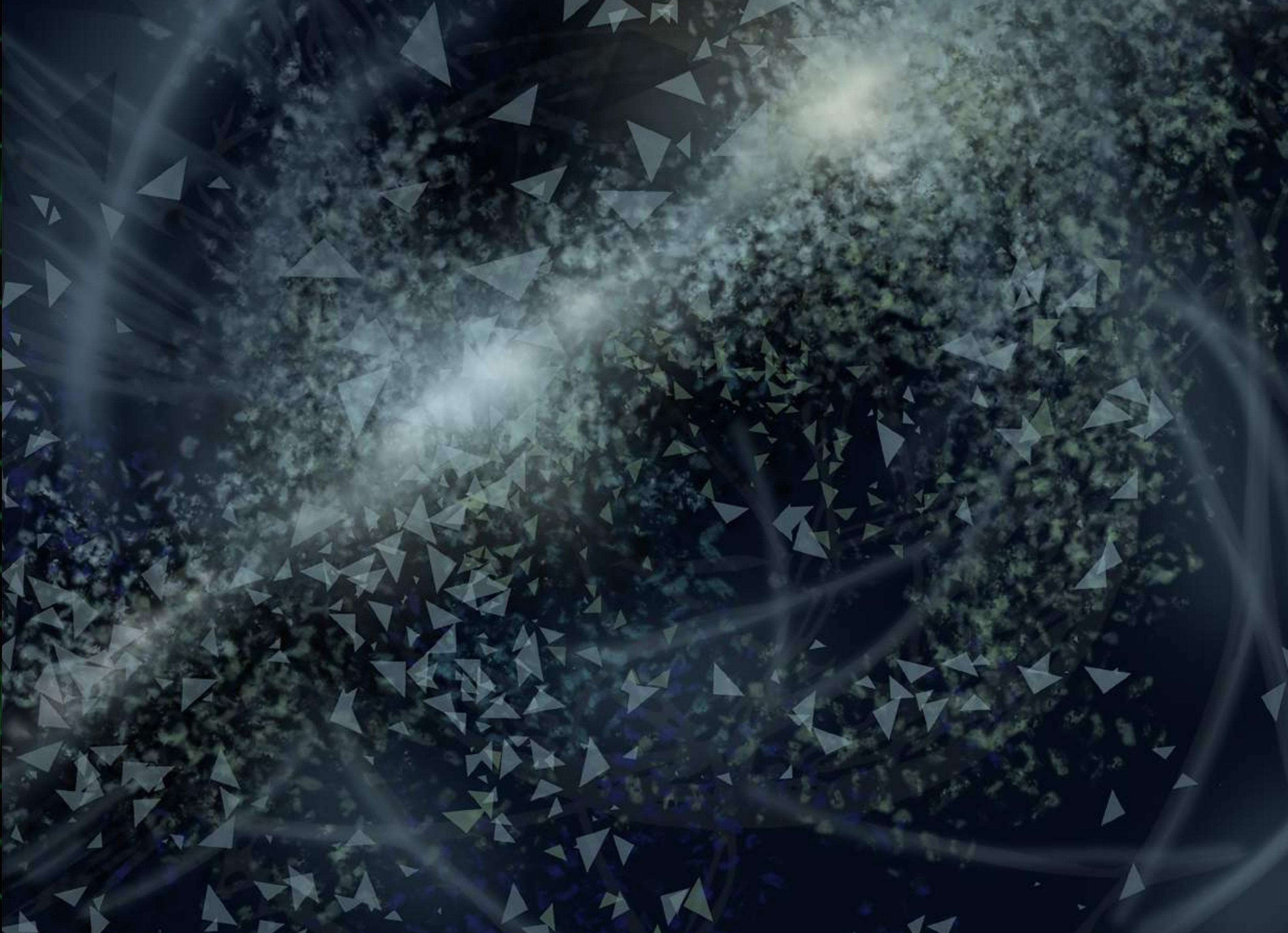
From then on out, in intervals of fractions of a second, the universe began to expand and cool. With this cooling the fundamental forces of space and time began to be shed and separate from one another, commencing their governance of the particles that were beginning to take shape. These bits and pieces of the early universe were rapidly forming, collapsing, and colliding in the restricted space. Suddenly, the strong interaction force separated from the electroweak (combination of electromagnetism and weak) force, thereby releasing a gargantuan amount of energy. In response to this further surge the universe's rate of expansion increased exponentially, its contents scattering forth with tremendous velocity. The dispersion of these particles across an increasingly vast space provided them with the opportunity to form into the subatomic particles that would become the bedrock of the known universe.

Recombination

377,000 Years After the Big Bang

When the expansion of the universe gradually slowed, freely distributed electrons and protons came together to form the first stable element: hydrogen. The advent of hydrogen, driven by the expansion and subsequent cooling of the universe, marked an important milestone in history of the universe. This new dawn was ushered in by a new particle: the photon. Photons, which before had been coupled with electrons and protons in a primordial soup of particles, ceased to be in a state of perpetual collision and followed their natural trajectory: out.

For the first time in history, there existed light as we experience it today. This light has become known as the cosmic microwave background, a remnant of an ancient epoch. While a normal, visible spectrum telescope detects only an expanse of darkness between celestial bodies, a radio telescope, sufficiently sensitive to detect even meager microwave radiation, can identify a faint glow that is not associated with stars or galaxies. This radiation, settled like a blanket over the entire universe, is the cosmic microwave background, the oldest light in the universe.



Reionization

13.7 Billion Years Ago

The early universe, then just 150 million years old, was awash with neutral hydrogen nuclei. They formed from the protons and electrons that, because of the high temperature of the universe, were previously unbound particles. Now that the universe had achieved physical substance gravity could begin to play a more prominent role. Clouds of nuclei began to form as atoms were pulled together into ever-denser objects. These early objects became massive and radiated tremendous amounts of energy, thereby ionizing the universe and converting matter into plasma quite similar to that which existed at the beginning. However, these isolated pockets of activity were scattered across a vast emptiness.

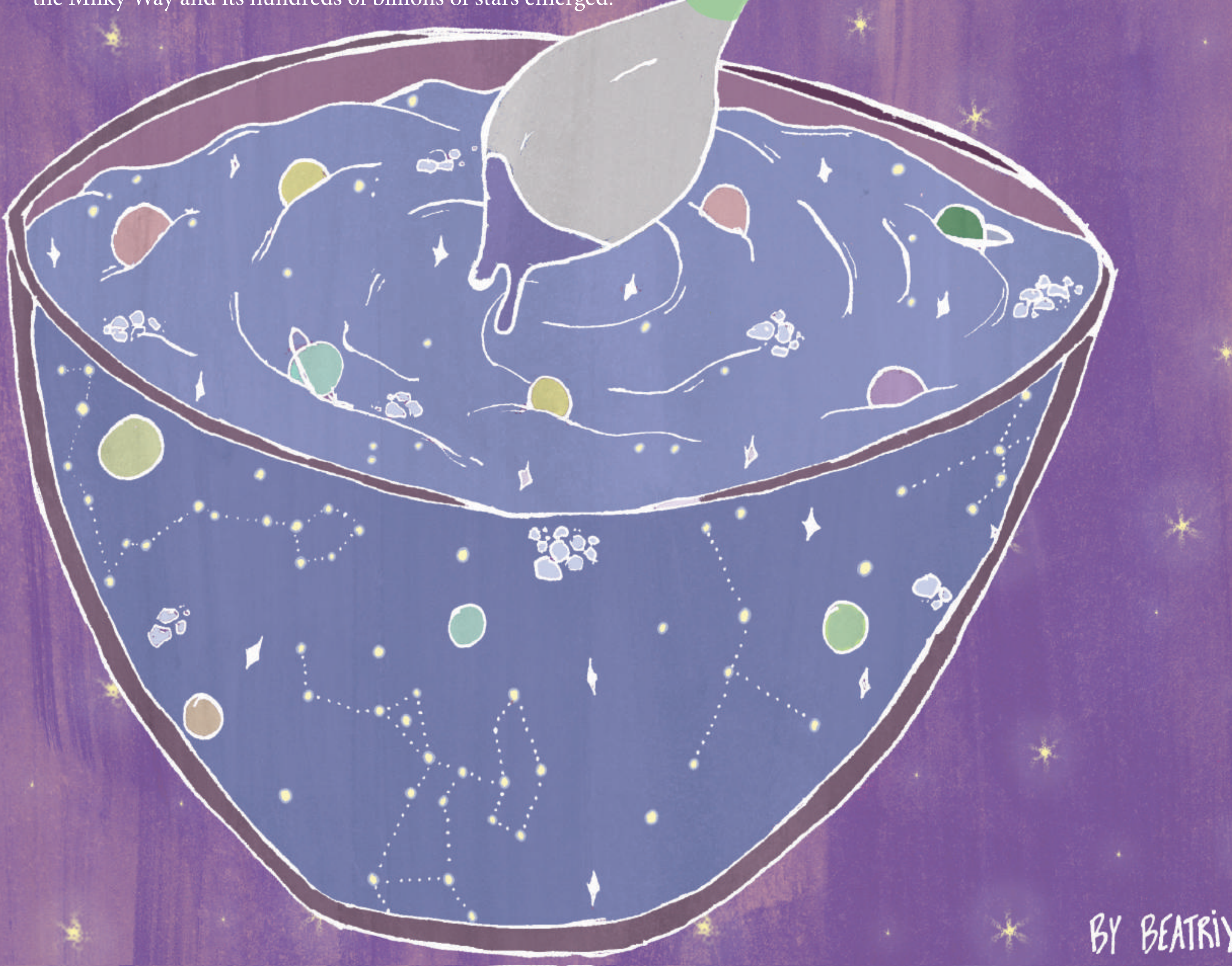
While it remains uncertain which objects provided the photons that reionized the universe, there are several likely candidates. First among these are dwarf galaxies, small galaxies composed of mere billions of stars (our own galaxy, the Milky Way, has over 100 billion). Because of their small size, dwarf galaxies are easily influenced by larger galaxies which, when they pass each other, can cause the former to warp, tear, and merge with the latter. This merging may produce a quasar, the next candidate for reionization energy. These active galactic nuclei are massive black holes that consume matter at an incredible rate. The friction generated by the matter being ripped and torn as it circles the black hole produces intense radiation. Being just beyond the point at which light can no longer escape—the event horizon—the radiation streams outward in a condensed jet of incredible luminosity. It is within this chaotic environment that our own galaxy began to form.

The Milky Way

13.2 Billion Years Ago

In the universe there exist three forms of energy: matter, dark matter, and dark energy. The first, and far less abundant, is of the type that we interact with every day. This is the stuff of neutrinos and leptons, protons and neutrons, atoms, compounds, molecules, organisms, oceans, and ice hockey arenas. It can be compressed to form solid molecular structures or diffused over great distances as a gas. Next is dark matter, a theoretical substance the existence of which is based on indirect observation. Its properties are inferred from its various gravitational effects upon visible matter. The third and most common form of energy is dark energy. It is hypothesized that dark energy accounts for 68% of all energy in the universe and permeates all space. Its existence was first proposed to explain the acceleration of the universe's expansion, now being the widely accepted cause thereof.

In order to create a galaxy, the cosmic conditions have to be just right. In the early universe, galaxies were primarily composed of gas and dark matter. As such, there were very few stars. As galaxies gained mass (normally by merging with smaller galaxies), the even distribution of matter and dark matter began to shift. Dark matter was relegated to the outskirts of emerging galaxies as gas accelerated inward. The condensed gas began orbiting the center of the new galaxy to become a very thin, rapidly rotating disk. As the spiraling arms funnel gas into the center of the young galaxy, the inner point becomes a dense, bar-shaped nuclei, operating as a galactic nursery that fosters stars. It is from such a beginning that the Milky Way and its hundreds of billions of stars emerged.

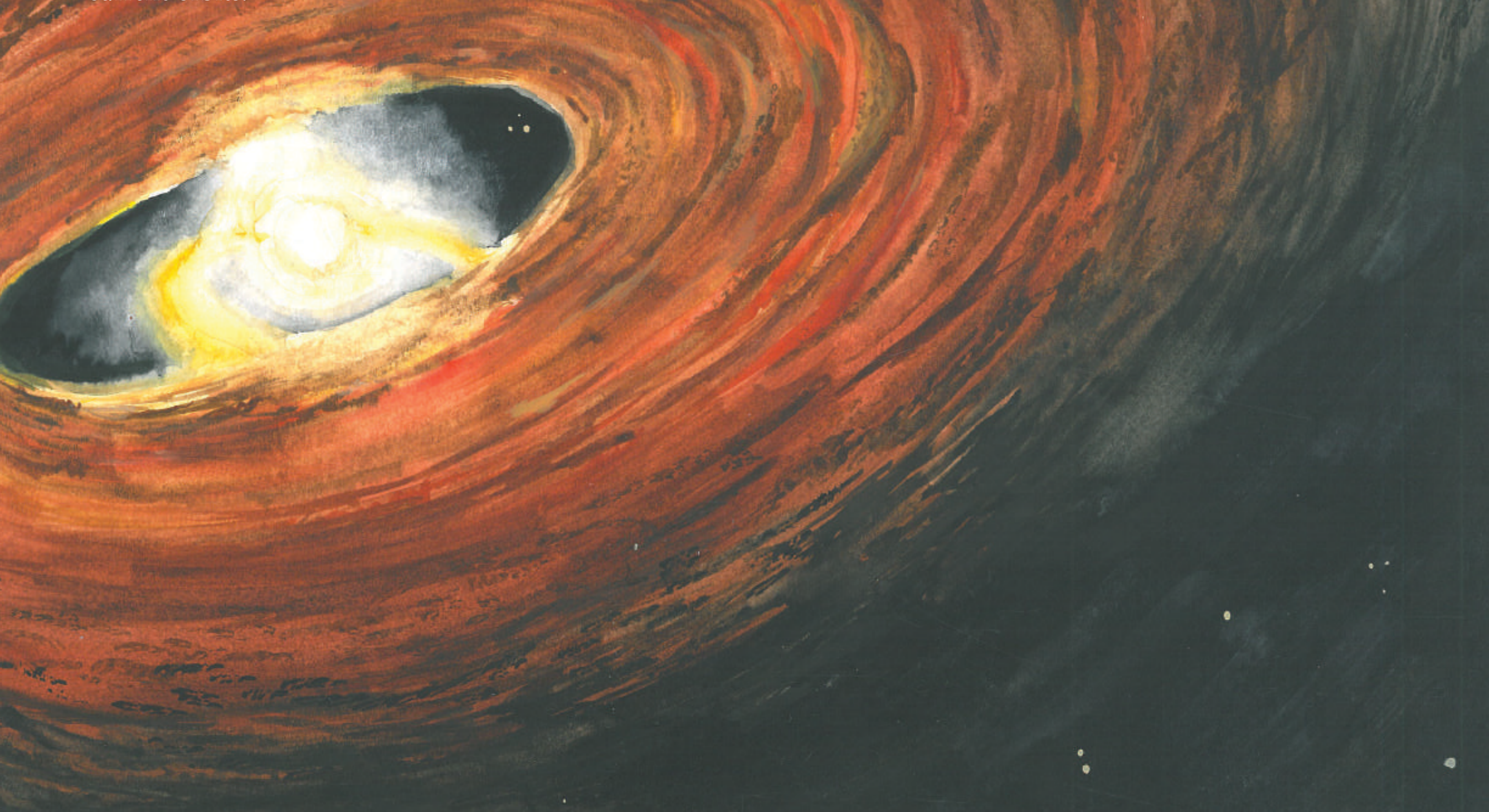


The Solar System

4.6 Billion Years Ago

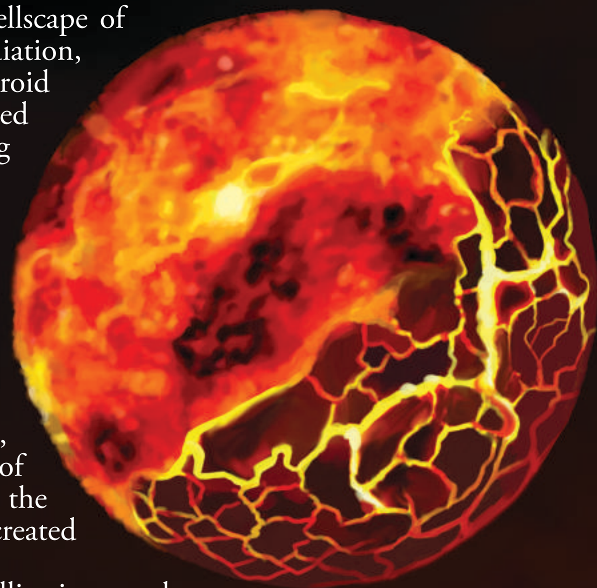
Our solar system resides in the Orion Arm, a minor spiral arm of the Milky Way. At a distance of 25,000-28,000 light-years from the Galactic Centre, it completes one revolution every 225-500 million years. 4.6 billion years ago all the matter that composes our sun and planets was distributed over a vast space. This molecular cloud was formed of primarily hydrogen, some helium, and a small collection of heavier elements fused by earlier generations of stars. It is thought that a shock wave generated by the supernova of a local star caused the cloud to ripple and fragment into over-dense regions, thus triggering the formation process. As a single fragment collapsed under its gravity, it drew in surrounding matter and contracted. As this occurred, a rotating disk of matter formed, spinning faster as its size decreased and its density increased. This process is very similar to the way in which a figure skater may increase the speed of their spin by drawing in their arms, a phenomenon known as the conservation of angular momentum. For our sun, colliding atoms began generating heat as competing forces caused a flattening of the nebula into a spinning protoplanetary disc. Once this disc became sufficiently dense it ignited, giving birth to a protostar. It was thus that our sun was born.

Within the orbiting tendrils of dust and gas, planets began to emerge. Gradually formed from orbiting dust grains, hunks of rock increased by centimeters a year over the next few million years. Around 100,000 years after the sun formed, the solar nebula was nearly out of dust. In its place orbited terrestrial embryos about 0.05 Earth masses. Through subsequent collisions and mergers, these objects would grew to become Mercury, Venus, Earth and Mars. Further influence of gravity and rotational forces transplanted them into their current orbits.



The Earth

4.4 Billion Years Ago



The early Earth was a hellscape of molten earth, solar radiation, and frequent asteroid collisions. Appropriately termed the Hadean Eon, this fledgling plane was totally inhospitable to complex life. Yet, even at this early date, liquid oceans existed on the surface. The evidence for water comes in the form of 4.4 billion year old zircon crystals that show indications of contact with water. It has been theorized that these oceans, despite a surface temperature of 230 °C, were made possible by the same protoplanet impact that created the moon.

Earth's only natural satellite is several times larger than any other satellite in the solar system. Rocks from its surface, courtesy of the Apollo program, show that not only is the Moon as old as the Earth, but it displays the same relative abundance of oxygen isotopes. Furthermore, Earth's spin and the Moon's orbit have similar orientations. These and other evidence support the theory that the Moon was formed after an indirect impact with an astronomical body the size of Mars known as Theia. Named after the Greek Titan and mother to the goddess of the Moon, the collision with Theia jettisoned chunks of the Earth's mantle into its own orbit. Eventually this debris merged to form a spherical body: the Moon.

The early atmosphere came into being at the same time the Moon was formed. The impact of Theia vaporized large quantities of rock and water that formed into a heavy atmosphere that shrouded the earth. Over the course of several thousand years, the dust condensed, settled, and left behind a heavy curtain of CO_2, which was dense enough to exert a considerable atmospheric pressure, thereby preventing the oceans below from vaporizing despite the heat. Yet, this early atmosphere was devoid of the oxygen that would eventually form the ozone layer and prevent harmful ultraviolet light from bombarding the surface. Under these conditions, it would be several billions years before the Earth would become a hospitable environment.