Facts About the Universe

by: Joshua '25

Chapter 8: The Information Paradox: A Black Hole Mystery

Information is the key to describing all individual objects and their unique properties in the universe. It reveals to us how things are different from each other and what used to be what. Information is not tangible. It is typically understood as a property of the arrangement of particles. This means that the atoms of the two objects can be the same, but the objects themselves are different from each other because of information.

If arranged in one way, carbon atoms can make up lonsdaleite. Carbon atoms can make graphene if arranged in another way. Carbon atoms arranged in different structures can also make graphite, diamonds, Q-carbon, fullerenes, carbon nanotubes, amorphous carbon, and carbyne. The atoms of all these substances are the same. What changes is the information, which affects the structure of each individual object.

The basic building blocks of everything in the universe are all the same. Without information to describe objects and their distinct properties, everything would be the same with the same properties. According to the theory of quantum mechanics, information is indestructible. Information might change its shape or properties, but it could never be destroyed. If you could somehow measure and analyze the information of every single atom, particle, and radiation waves in the universe, then you could probably solve every single mystery about the universe itself. Theoretically, you could see the entirety of the universe's history and even see the Big Bang.

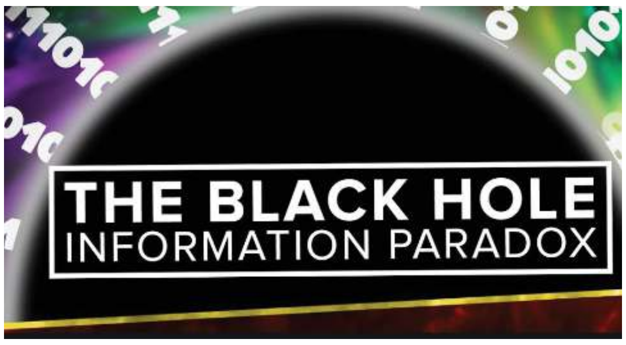
Here is where the information paradox starts and how black holes confuse us. Information tells us how things are different. Black holes take different objects with different information and make them the same. They destroy or at least permanently alter information. This creates the information paradox. It is a baffling, serious, and confusing problem. Most of our laws and physics about the universe are based upon the rule that information can never be lost. Without information, everything is relative. When dealing with understanding reality, there need to be absolutes.

There are several possibilities and theories about the results of the information paradox. One possibility is that information is irretrievably lost. The advantage of this is that it seems to be a direct consequence of relatively non-controversial calculation based on semiclassical gravity. The disadvantage is that it violates unitarity.

Another theory is that information gradually leaks out during black-hole evaporation. The good thing about this is that this theory is Intuitively appealing because it qualitatively resembles information recovery in a classical process of burning. The problem with this is that it requires a large deviation from classical and semiclassical gravity, even for macroscopic black holes.

A third prospect is that information suddenly escapes out during the final stage of black-hole evaporation. The good thing about this prospect is that a significant deviation from classical and semiclassical gravity is needed only in the regime in which the effects of quantum gravity are expected to dominate. However, just before the sudden escape of information, a very small black hole must be able to store an arbitrary amount of information, which violates the Bekenstein bound.

A different alternative is that information is stored in a Planck-sized remnant. No mechanism for information escape would be needed. Unfortunately, to contain the information from any evaporated black hole, the remnants would need to have an infinite number of internal states. It has been argued that it would be possible to produce an infinite amount of pairs of these remnants since they are small and indistinguishable from the perspective of the low-energy effective theory. Another speculation is that information is stored in a large remnant. This would mean that the size of the remnant increases with the size of the initial black hole, so there is no need for an infinite number of internal states. The problem is that Hawking radiation must stop before the black hole



reaches the Planck size, which requires a violation of semiclassical gravity at a macroscopic scale.

The next proposal is that information is stored in a baby universe that separates from our own universe. This scenario is predicted by the Einstein–Cartan theory of gravity, which extends general relativity to matter with intrinsic angular momentum. No violation of known general principles of physics is needed. Sadly, it is difficult to test the Einstein–Cartan theory because its predictions are significantly different from general-relativistic ones only at extremely high densities.

The final thesis is that information is encoded in the correlations between the future and the past. This would mean that semi- classical gravity is sufficient. On the other hand, it contradicts the intuitive view of nature as an entity that evolves with time.

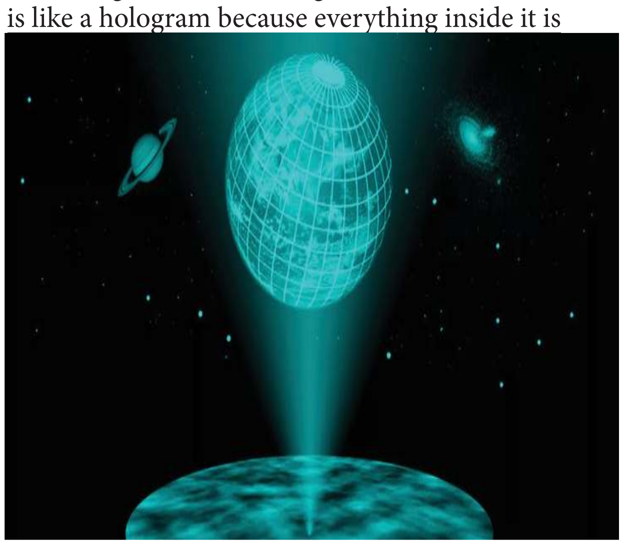
The three main results of the information paradox is that information is lost, information is hidden, and information is safe. If information is lost, then we would have to trash many of our current laws of physics and try to make new laws. That is frightening but also a little exciting at the same time. If information is hidden, then it would be transferred to a different place, where we could not observe or interact with it. This would not be helpful, but technically, the information would not be lost. If information was safe and not deleted, then the black holes store information on their surface. The black hole would get slightly bigger with every addition of information. This solution is called the holographic principle. If it is correct, then this would mean that everything we thought about the universe is wrong. The holographic principle basically states that the universe is a hologram, but this is a topic for another chapter. We may never know the true mechanics of the idea of information, but we may learn what happens to it.

Chapter 9: The Holographic Principle

The holographic principle states that the universe is a hologram and that black holes store information from the particles of an object they consume on its surface in pixels that are unbelievably tiny. This basically means that black holes are like super hard drives. It infers that black holes store information differently but that the content of data is the same. The holographic principle ties in with the third possibility of the black hole information paradox, which states that information is safe in black holes.

The problem with the holographic principle is that if it is true, then it means that everything we thought about the universe is wrong. The holographic principle is a tenet of string theories and a supposed property of quantum gravity that states that the description of a volume of space can be thought of as encoded on a lower-dimensional boundary to the region similar to a light-like boundary like a gravitational horizon. It was inspired by black hole thermodynamics. If information is stored on the edges of a black hole, then hawking radiation can learn about it and transfer it somewhere else. Information is not lost when black holes fade due to hawking radiation if the holographic principle is correct and the information paradox is solved. Our laws of physics would not need to be rewritten.

But reality would be quite different if this were the case. If everything that fell into a black hole was stored on it as encoded information, then that would mean that 3D objects that fell into the black hole would be converted into 2D on its surface. You would not see anything on black holes from the information that fell in because reflected light that allows you to view cannot escape black holes. If true, this would mean that the transparent 2D details on the event horizon could make up the 3D black hole. There is a name for this: a hologram. A hologram is a three-dimensional photo, a flat piece that encodes a 3D image. There is the argument that a black hole is like a hologram because everything inside it is



encoded on its event horizon in this case. Theh olographic black hole would grow slightly for every bit of information it consumes. It creates more space or surface area for the new information. Th einf ormation would get spread across its surface. Ther e is the theory that if this duality for 2D and 3D works, then it could work for the entire universe, and you in it. You really might be some coded information on the surface of a black hole. You would still experience your usual 3D life as 2D information.

Since a person encoded on a black hole would probably not realize that they were, we might share the same fate, according to the theory. You could be stretched out on the surface of a black hole and not even know it. Theide als surrounding the holographic principle are extremely confusing. What is even more confusing is the math around this principle. Ther e are terms and variables such as entropy, mass-energy equivalence ($E = mc2$), logarithms, Planck units, δM c2, and microstates that tend to boggle the mind. Overall, the holographic principle that concerns a crazy 2D and 3D duality have not been proven, and it likely never will be.

What do you want to know about the Universe?
Email *(redacted)* and Mrs. Gage will forward your question on to Joshua!

Facts About the Universe *Continued*

Chapter 10: The Infeasibility of Faster than Light Speed Speeds

Traveling faster than the speed of light is a staple of science fiction. Whether it's jumping into hyperspace, engaging the warp drive, or opening the stargate, most stories about interstellar travel include these. While some of these jumps are called "jumping to light speed," instantaneously jumping from one system to another is way faster than the speed of light.

Particles that have mass require energy to accelerate them. The closer to the speed of light you get a particle, the more power is needed to go faster. This is because the particles themselves get more massive in proportion to the increased velocity. In short, the quicker you go, the heavier you get. Thanks to this inconvenient truth, if you wanted to accelerate a single electron to 'light speed,' you would need infinite amount energy due to the electron becoming infinitely heavy. There isn't enough energy in the entire universe to propel just a single electron to the speed of light. But then how does light travel at "light speed?"

Since photons don't interact with the Higgs field, it means any speed limit doesn't bound them. They're free to move at the fastest possible speed – their own "light" speed. Why isn't the speed of light slower or faster than 186,282 miles per second? It's because that exact speed is a fundamental constant of our universe. More generally, it usually is impossible for information or energy to travel faster than light. One argument for this follows from the counter-intuitive implication of special relativity known as the relativity of simultaneity. If the spatial distance between two events A and B is greater than the time interval between them multiplied by light, then there are frames

of reference in which A precedes B, others in which B precedes A, and others in which they are simultaneous. As a result, if something were traveling faster than light relative to an inertial frame of reference, it would be moving backward in time relative to another frame, and causality would be violated.

In such a frame of reference, an "effect" could be observed before its "cause." Such a violation of causality has never been recorded and would lead to paradoxes such as the tachyonic antitelephone. A tachyonic antitelephone is a hypothetical device in theoretical physics that could be used to send signals into one's past. Albert Einstein presented a thought experiment of how faster-than-light signals can lead to a paradox of causality.

A theorized way to travel faster than light is using wormholes and old string theory. String theory states that after the Big Bang, tiny quantum fluctuations caused many minuscule wormholes in space with small strings called cosmic strings weaved in them. After the universe expanded after the Big Bang, these ends of wormholes were pulled light-years apart. The traversable wormhole, which could create a shortcut between arbitrarily distant points in space. Travelers moving through the wormhole would not locally move faster than light traveling through the wormhole alongside them. Still, they would be able to reach their destination faster than light traveling outside the wormhole. However, wormholes break the universe in fundamental ways, potentially creating time travel paradoxes and messing up the structure of the universe. That is why many scientists believe that wormholes do not exist.

There are other theoretical ways to travel faster than light like the Alcubierre drive or the Heim theory, but they are tough to prove and are doubted widely by other scientists. In short, traveling faster than light is impossible for particles that interact with the Higgs Field and that if faster than the speed of light speeds were possible, then it would break spacetime, cause paradoxes, and violate and ruin a bunch of physics.

Chapter 11: The Strangest Planets Ever Found

HD 209458 b, located 150 light-years away from planet Earth, in the Pegasus constellation, and is the first exoplanet to be discovered in transit of its orbiting star. It is 30% larger than Jupiter, while its orbit is 1/8th of Mercury distance from the sun. Naturally, its temperature is extremely high: about 1832°F. This gas planet, under the extreme heat and immense pressure, has faced evaporation of different atmospheric gases that escape its gravitational field in a stream, including hydrogen, carbon, and oxygen.

The planet CoRoT-7b is a strange and mysterious planet outside the solar system, and the first rocky planet discovered orbiting a star other than the sun. It is believed to have been a giant gas planet initially, like Neptune or Saturn, but due to its proximity to its star, CoRoT-7, it gradually lost its gas and atmosphere layers. Since it is tidally locked, it always faces its star on one side where temperature can be 4000°F, while the temperature on the side facing away is as about 350°F. The conditions lead to rock snow: vaporized rocks that fall as liquid rock snow, and solidify on the surface of the planet. It would kill you if you happened to be on that planet.

The exoplanet PSR 1620-26 b is probably the oldest planet of the universe, old enough to defy the traditional astrophysical models. It is triple the age of Earth and is thought to be just a billion years younger than the universe itself, when traditionally, it is believed that planets cannot be as old as the universe, because, 13.8 billion years ago, at the time of the big bang, the materials required for a planet to form were not there in the universe. It orbits a binary star consisting of a white dwarf star and a pulsar, amongst the globular cluster of stars in the Scorpius constellation.

HD 106906 b is the "forever-alone guy" of planets as it hangs out, all by itself, in the Cruz constellation, revolving around its host star at a distance 60,000,000,000 miles, over 20 times the space between Neptune and the Sun. Located nearly 300 light-years away from the Earth, it is part of the "Super-Jupiter" class planet, which is above 11 times larger than Jupiter, is thus too far away from the host to gather raw material needed for its formation. Astrophysicists hypothecate that it is a failed star or perhaps a rogue planet.

J1407 b was discovered in 2012. It is located 400 light-years away from Earth. What is astounding about this planet is that it has a system of enormous planetary rings, and these rings are 200 times larger than the ones around Saturn. The rings are so big that if they belonged to Saturn, it would almost dominate the Earth's sky, appearing larger than the Moon, and scientists also observed a 56-day eclipse of its host star. The gaps between the rings are believed to represent exomoons orbiting this exoplanet. If that were the case, then J1407 b could have many more exomoons than Saturn or Jupiter.

Gliese 436 b is one of many murderous exoplanets under the Gliese catalog. It is about 20 times bigger than Earth and is roughly the size of Neptune. The planet is 4.3 million miles away from its host star, in comparison to Earth, which is 93 million miles from the sun. The temperature on the planet is 822°F, and its surface is covered with burning ice. The immense gravitational force of the planet keeps the water molecules too densely packed to evaporate, and thus, prevents them from escaping the planet.

Discovered in 2004, 55 Cancri e, at twice the Earth's size and eight times its mass, is called "Super Earth." Aside from graphite and other silicates, its main component is diamond. It is made of crystallized diamond, with 1/3rd of its mass being a pure diamond. Once a star in a binary system, its partner started eating at it, leaving only the gem core. Its temperature is 3900°F. Its Earth value is $26.9 nonillion, 384 quintillion times Earth's GDP of $74 trillion. Mining only 0.182% of it would pay off the total debt of $50 trillion of all the governments in the world.

OGLE-2016-BLG-1195Lb is an icy exoplanet that can be found a whopping 13,000 light-years from our solar system. Its temperatures range from -220 degrees Celsius (-364 °F) to -186 degrees Celsius (-302 °F), which is why it's sometimes called the "iceball planet." All the ice on OGLE-2016-BLG-1195Lb is thought to be freshwater. Although this is good, it's unlikely that we will be able to use this water in the foreseeable future.

TrEs-2b, the planet of eternal night, is the darkest planet ever discovered orbiting a star. This alien world is less reflective than coal. Inside its atmosphere, you'd be flying blind in the dark. The air of this planet is as hot as lava. TrES-2 b is a gas giant exoplanet that orbits a G-type star. Its mass is 1.49 Jupiters, it takes 2.5 days to complete one orbit of its star, and is 0.03563 AU from its star. Its discovery was announced in 2006. Its atmosphere contains vaporized sodium, potassium, and titanium oxide, all of which absorb light. However, it is still a mystery as to why

the planet is so dark, a mystery that may never be solved. Interestingly, at 1800°F, it turns hot enough to emit a dull, reddish glow, which is visible, probably because of all the absorbed light.

Perhaps one of the most interesting exoplanets on this list, HD 189733b, which is 63 light-years away. Weather there is deadly. The planet's cobalt blue color comes from a hazy, blow-torched atmosphere containing clouds laced with glass. Howling winds send the storming glass sideways at 5,400 mph, whipping all in a sickening spiral. It's death by a million cuts on this slasher planet! A silica-concentrated atmosphere causes the planet's clouds to rain molten glass, which hardens as it falls. HD 189733b's wind pushes the glass at such speeds that the shards fly through the air horizontally, slicing up everything in their path. Imagine getting stuck in that storm!

The doomed planet WASP-12b is a hot Jupiter that orbits so close to its parent star, Wasp-12, it's being torn apart. It takes this alien world only 1.1 days to completely circle its sun. The star's scorching heat is slowly stripping away and devouring the planet's atmosphere. In 10 million years, this alien world could be completely consumed. Almost two times the size of our Jupiter, WASP-12b is a sizzling gas giant whose temperature is approximately 4,000 degrees Fahrenheit (2,210 degrees Celsius). Gravity causes enormous tidal forces which are stretching the planet into the shape of an egg. Its gasses are being eaten up by its host star.

GJ 1214b is a huge "Waterworld" three times the size of Earth that can be found 42 light-years away from our solar system. Earth's water is equal to 0.05 percent of its mass, while GJ 1214b's water contributes 10 percent of its mass! GJ 1214b is thought to have oceans that may reach depths of as much as 1,000 miles. In contrast, the deepest part of our own oceans is the Mariana Trench, seven miles deep.

SR J1719-1438 b is another planet made of pure diamond. A large, carbon-based planet with a diameter roughly five times that of Earth, PSR J1719-1438 b can be found about 4,000 light-years away from our solar system. Due to immense pressure caused by the planet's gravitational pull, the carbon has been condensed, forming a gigantic diamond. This exoplanet orbits a millisecond pulsar named PSR J1719-1438. Astronomers believe that the pulsar was once a massive star that became a stellar corpse in a supernova. These millisecond pulsars are supposedly formed by eating the material from a companion star. In this case, the companion star was probably a white dwarf, which is what our sun will become when it dies. A white dwarf is a remnant that has no more nuclear fuel. Here, the millisecond pulsar probably ate the material from its companion white dwarf. With only 0.1 percent of its mass left, the white dwarf then formed an exotic crystalline companion to the pulsar—the diamond planet.