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Editor's Note

The 'second quantum revolution' that began nearly forty-five years ago with the demonstration of quantum entanglement by Clauser, Aspect and Zeilinger has led to the development of 'quantum technologies' like quantum computation, quantum communication, quantum teleportation, quantum sensing, etc. Such technologies happen to be 'hot' subjects for big multinational companies and laboratories. The first article give an introductory account of quantum technologies and recent developments made in the field. Albert Einstein's sayings about various matters are the most sought-after quotes worldwide. A small selection of them is available here. While many people might be familiar with the mechanics of fixed-wing aircraft, the way helicopters achieve lift, thrust and propulsion with the help of only rotary blades is not so well known. Here we have an article that explains briefly how helicopters hover, fly and turn by manipulating the pitch of the rotating blades ingeniously – hence showing the complexity in operating a helicopter. P A M Dirac is rightly regarded as one of the greatest theoretical physicists of the twentieth century. We have an article about his life and contributions, along with interesting photographs. Such biographical articles are really interesting and essential to inspire students. Scientists are also human beings with all kinds of strange behaviours! There is an interesting collection of anecdotes related to scientists. Alan Turing is regarded as the 'father' of computer science. There is a detailed article about his life and legacy. Even though quantum theory has been very successful in predicting the outcomes of measurements in the atomic and the nuclear world, its 'interpretation' or 'understanding' is not a settled matter as explained in an article by a distinguished scientist, Sean Carroll. Black Hole evaporation was predicted by Stephen Hawking. But the mechanism of evaporation is quite complicated, as explained in an article here. Another one of the most intriguing questions is about the existence of alien life in the universe. A detailed article gives an account of the subject that is still unresolved. While the existence of dark matter is established satisfactorily, the origin and constitution of dark matter are still not clear – it happens to be one of the most challenging problems of physics now. We have an article with a different perspective on dark matter for all to consider. An article about human travel to Mars, giving the challenges one has to face, can be found here. A popular-level, but detailed, article in Kannada about Black Holes makes interesting reading. Finally, we have reports about various academic activities of KPA members, the webinars held and the recently concluded national conference on quantum science & technology, artificial intelligence in physics teaching and materials science at Vijaya College, Bengaluru, are available for all to gauge the progress of KPA! We have selected interesting and useful articles by distinguished authors that are available in the open source for inclusion in this newsletter.

We would like to know your opinions about the articles in this issue and we invite you to contribute suitable articles to the next issue of the KPA newsletter.

KPA wishes to thank Dr. (Mrs.) Muktha B. Kagali for designing this Newsletter at short notice, that too free of charge.

- Chief Editor

The Quantum Revolution: Unlocking the Future

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Most of us are born in the digital age, surrounded by computers and smartphones. Some of us, who were born a little earlier, have witnessed the evolution of technology firsthand, starting with the emergence of radio and telephones, followed by television, and eventually, computers. Today, computers have become an integral part of our daily lives, with even smartphones functioning as compact computers, initially designed for voice communication but now capable of much more.

Despite their widespread use, the underlying technology behind computers remains a mystery to the common user. A vast amount of expertise and technical innovation goes into making them function. Computers can perform a wide range of complex tasks, from playing videos to executing intricate calculations. At their core, however, all these operations are mathematical and can ultimately be reduced to the simple operation: addition. Addition itself can be constructed using fundamental logical operations such as AND and OR.

For a machine to process logical operations, it requires a number system. Computers use the **binary number system**, which relies on **Boolean logic**. To implement this, computers need hardware components that act like switches—devices that can exist in one of two states: **ON or OFF**. These two states correspond to the numbers **1 and 0** in binary. Signals are used to induce transitions between these states, forming the foundation on which all logical and arithmetic operations in computing are built.

The hardware capable of being a switch that can be toggled with an electrical signal is a transistor. The **transistor** was invented in **1947** by **John Bardeen, William Shockley, and Walter Brattain** at Bell Labs. It was developed as a replacement for vacuum tubes, which were bulky, inefficient, and prone to failure. The trio discovered that by using a semiconductor material (initially germanium), they could control electrical signals and amplify them efficiently. This breakthrough led to the first **point-contact transistor**, followed by the more stable **bipolar junction transistor (BJT)**.

The invention of the transistor revolutionized electronics, leading to the development of smaller, faster, and more reliable devices. It paved the way for modern computers, integrated circuits, and nearly all the digital technology we use today. In recognition of their work, the inventors were awarded the **Nobel Prize in Physics in 1956**.

What are Logic Gates?

Logic gates take inputs (0s and 1s) and produce outputs based on logical rules. Let’s take two simple examples:

[1] **OR Gate**: Picture an enthusiastic dad with two kids. If **either** child wants to go to a movie, he happily agrees. This is like an OR gate – if at least one input is 1 (yes), the output is also 1 (yes).

[2] **AND Gate**: Now, imagine a lazy dad. He will only take his kids to the movie if **both** insist. This is like an AND gate – only when both inputs are 1 (yes), the output is 1 (yes).

[3] Similarly, one can conceive many such logical operations using another kind of gate. One such gate is called a NAND Gate. It is possible to show that all gates can be constructed using combinations of NAND gates.

[4] By combining suitable logic gates, we can create an **adder**, a circuit that performs addition. Since computers break down complex operations into additions, they can perform virtually any calculation using these gates.

The Limits of Classical Computers

Classical computers are powerful, but they have their limits. Some problems are like an endless maze, for solving such problems, which even the fastest computers take years to find the right path. Encryption, drug discovery, complex simulations—these are mountains too steep for classical machines to climb. Nature, however, has secrets yet to be unlocked, and that's where quantum computing comes in.

Moore's Law and Its Possible End

For decades, **Moore's Law** has predicted that the number of transistors on a microchip doubles approximately every two years, leading to exponential growth in computing power. This trend has fueled rapid advancements in technology, making devices smaller, faster, and more efficient. However, as transistors shrink to atomic scales, we are approaching physical limits—quantum effects such as electron tunneling begin to disrupt reliable computation, making further miniaturization increasingly difficult.

This impending slowdown, often referred to as the **end of Moore's Law**, presents a major challenge for the future advancement of computing. **Quantum computing**, however, offers a new path forward. Instead of relying on transistor-based architectures, quantum computers harness the principles of **superposition** and **entanglement** to process information in entirely new ways. By leveraging these quantum effects, we could solve complex problems beyond the reach of classical computers, potentially ushering in a new era of computational power that extends far beyond Moore's Law.

From Classical to Quantum

Classical computers use **bits** (0s and 1s) to store and process information. But, quantum computers use something even more magical: **qubits**.

A classical bit is like a tiny candle—it can be either lit (1) or unlit (0). A **qubit**, however, behaves differently. Imagine a dimmer switch instead of a simple light switch. Instead of being only fully **on** or **off**, it can be somewhere in between. However, here's the trick—if you check the switch, you'll always find it either

fully **on** or fully **off**. The moment you measure it, all those in-between possibilities disappear. This strange behavior is called **superposition**.

What are the Key Concepts in Quantum Computing?

1. **Qubits – The Building Blocks**
   Unlike classical bits, **qubits (quantum bits)** can exist in **superposition**, meaning they can be in a state of 0, 1, or both at the same time. This allows quantum computers to perform multiple calculations simultaneously, exponentially increasing processing power.

2. **Superposition – Doing More with Less**
   A classical computer with **N bits** can represent only one of 2^N possible states at any moment. However, **N qubits** in superposition can represent **all** of these states at once, leading to massive parallelism in computation.

3. **Entanglement – Quantum Connections**
   When two qubits become **entangled**, the state of one instantly influences the state of the other, no matter how far apart they are. This phenomenon enables ultra-fast data processing and secure communication.

4. **Quantum Interference – Controlling Probabilities**
   Quantum algorithms use interference to manipulate probabilities, enhancing the likelihood of correct answers while reducing incorrect ones.

Quantum Supremacy: A New Era of Computing

The quest for **quantum supremacy**—the point at which a quantum computer can outperform the most advanced classical supercomputers—has been a long-standing goal in the field of quantum computing. The foundations of this idea were laid in the 1980s when **David Deutsch** introduced the first quantum algorithm, demonstrating that quantum mechanics could fundamentally enhance computation. His **Deutsch algorithm** showed that a quantum computer could determine whether a function is constant or balanced with just one evaluation, whereas a classical computer would require at least two. This may seem like a minor advantage, but it was the first proof that quantum computers could outperform classical ones in specific tasks.

This concept of quantum advantage took a massive leap with the introduction of two groundbreaking quantum algorithms: Shor's algorithm **and** Grover's algorithm**. These algorithms provided concrete evidence that quantum computers could solve certain real-world problems exponentially faster than classical machines, leading to practical applications in** cryptography, search algorithms, and optimization problems**.**

Shor's Algorithm: Breaking Modern Cryptography

One of the most critical problems in classical computing is **integer factorization**—breaking down a large number into its prime factors. This is the foundation of **RSA encryption**, which secures online banking, emails, and sensitive government communications. RSA encryption relies on the fact that classical computers struggle to factorize very large numbers within a reasonable time. For instance, a 2048-bit RSA key would take classical computers **thousands of years** to crack using the best-known classical algorithms.

In 1994, **Peter Shor** devised an algorithm that could factorize large numbers **in polynomial time** using quantum computers. While classical algorithms scale exponentially with the size of the number N, Shor's algorithm operates in $\mathbf{O((\log N)^3)}$ time, making it dramatically more efficient. If a sufficiently powerful quantum computer were built, it could render RSA encryption obsolete overnight. This has led researchers to explore **post-quantum cryptography**, aiming to develop encryption methods resistant to quantum attacks. Governments and organizations worldwide are now in a race to secure digital infrastructure against potential quantum threats.

Grover's Algorithm: Faster Database Search

While Shor's algorithm threatens encryption, **Grover's algorithm** addresses another fundamental problem—**database searching**. In classical computing, searching an unsorted database of **N** entries requires **O(N)** time in the worst case. For example, if you were looking for a specific record in a database of one million entries, a classical search algorithm might need to check up to one million entries before finding the desired one.

Grover's algorithm, developed in 1996, offers a quadratic speedup, allowing a quantum computer to search the same database in $\mathbf{O(\sqrt{N})}$ time. This means that instead of one million operations, a quantum computer would only need around **1000**. While this may not be as dramatic an improvement as Shor's algorithm, it has significant implications for **big data, artificial intelligence, optimization problems, and cybersecurity**.

Quantum Supremacy: A Demonstration by Google

The theoretical advantages of quantum computing remained largely hypothetical until **Google's Sycamore processor** demonstrated quantum supremacy in 2019. Google's quantum computer performed a task in **200 seconds** that would take the world's fastest classical supercomputer, Summit, approximately **10,000 years** to complete. This task involved generating a sequence of random numbers and verifying their quantum interference patterns—a problem specifically designed to be challenging for classical machines but easy for quantum ones.

While this achievement was largely symbolic (since the task had no immediate practical use), it was a pivotal milestone. It provided the first tangible proof that quantum machines could surpass classical ones in computational speed. Despite skepticism from some researchers, who argued that a classical computer with optimized algorithms could perform the task in a shorter time—Google's experiment was widely regarded as the **beginning of the quantum era**.

Beyond Supremacy: Practical Applications of Quantum Computing

Quantum supremacy is only the first step toward practical quantum computing. The real challenge now lies in scaling quantum computers and applying their power to **real-world problems**. Some of the most promising applications include:

1. **Applications in Drug Design:** One of the most promising applications of quantum simulation is in **drug discovery and material science**. Traditional computational chemistry relies on methods like **density functional theory (DFT)** and **molecular dynamics**, which struggle with large molecules due to the exponential growth of required computational resources. Quantum computers, however, can:

    a. **Precisely simulate molecular interactions** at the quantum level.

    b. **Model protein-ligand binding** with unparalleled accuracy.

    c. **Predict new drug candidates** faster by solving Schrödinger's equation directly for complex molecules.

    This ability to perform **direct Hamiltonian-based calculations** allows researchers to design new pharmaceuticals, optimize catalysts, and even develop novel materials for energy storage, all with significantly reduced computational costs compared to classical methods.

2. **Artificial Intelligence and Machine Learning** – Quantum computing has the potential to enhance machine learning algorithms by improving optimization, data classification, and generative models. Quantum-enhanced AI could revolutionize fields such as natural language processing and image recognition.

3. **Optimization Problems –** Many real-world problems, from **supply chain logistics** to **financial modeling**, require solving complex optimization problems. Quantum algorithms, such as **quantum annealing**, could provide exponential speedups in finding the best solutions.

4. **Climate Modeling –** Simulating climate systems requires enormous computational power due to the vast number of interacting variables. Quantum computers could allow scientists to model global climate systems more accurately and develop better strategies for combating climate change.

5. **Secure Communications –** While quantum computing threatens classical encryption, it also opens new possibilities for **quantum cryptography**, such as **quantum key distribution (QKD)**, which provides theoretically unbreakable encryption based on quantum mechanics.

As quantum hardware continues to improve, direct Hamiltonian simulations could revolutionize not just drug design but a wide range of fields, including climate modelling, superconductivity research, and quantum chemistry.

Challenges in Quantum Computing: Understanding Coherence, Fidelity, and Errors

Quantum computers have the potential to solve problems that are impossible for classical computers. But before they can truly revolutionize technology, scientists need to overcome some major challenges.

The three biggest hurdles are **coherence, fidelity, and errors**—let's break them down in simple terms.

1. Coherence: The Fragile Nature of Qubits

Imagine trying to balance a spinning coin on your fingertip. If there's the slightest vibration, the coin will fall. In the quantum world, qubits (the building blocks of quantum computers) are like those spinning coins—they exist in delicate states of superposition, where they can be both 0 and 1 at the same time. However, even the tiniest disturbance from their surroundings—like heat, magnetic fields, or stray atoms—can destroy this state. This is called **decoherence**, and it's one of the biggest obstacles in building a reliable quantum computer.

To keep qubits stable, researchers cool them to temperatures colder than outer space and isolate them as much as possible. But despite these efforts, coherence times (the time a qubit stays in a useful state) are still very short, often just microseconds or milliseconds.

2. Fidelity: The Trustworthiness of Quantum Operations

Now, imagine you're whispering a secret message through a long chain of people. If even one person mishears a word, the message gets distorted. In quantum computing, **fidelity** refers to how accurately quantum operations and calculations are performed. Because quantum states are so sensitive, even small imperfections in how qubits interact can lead to incorrect results.

Low fidelity means a quantum computer is making a lot of small mistakes, which add up over time. Scientists are working on ways to improve fidelity by refining hardware, using better materials, and developing error correction techniques.

3. Errors: The Unavoidable Problem

Unlike classical computers, which can use error-checking methods like redundancy (storing multiple copies of data), quantum computers face a unique challenge: **measuring a qubit destroys its quantum state**. This means traditional error-checking doesn't work. Quantum errors can come from many sources—noise from the environment, imperfect hardware, or even the natural unpredictability of quantum systems.

To combat errors, scientists use **quantum error correction**, which involves encoding quantum information across multiple qubits in a way that allows mistakes to be detected and corrected without directly measuring the qubits. However, this requires a **lot** of extra qubits—sometimes dozens of physical qubits just to maintain a single reliable "logical qubit".

What is Quantum Hardware?

Now that we have a fairly clear idea of the logic behind Quantum Computing, let us understand what the hardware requirements are to execute quantum computers. Classical computers rely on transistors, but quantum computers use **atoms and particles** to create qubits. These qubits are like cosmic dancers, moving in ways that defy intuition. There are different ways to make qubits, including:

a) **Superconducting Qubits**: These use circuits made from superconducting materials, cooled to temperatures colder than deep space.

b) **Ion Trap Qubits**: These use individual atoms trapped and controlled by electromagnetic fields, suspended in silence like stars held in a cosmic net.

c) **Photon-based Qubits**: These use light particles, whispering information across space at the speed of light.

d) **Diamond Color Center Qubits**: These use atomic-scale defects in diamonds, such as **Nitrogen-Vacancy (NV) centers**, to store and manipulate quantum information. They are particularly useful for **quantum sensing** and **quantum networking** due to their long coherence times even at room temperature.

e) **Neutral Atom Qubits**: These use individual **neutral atoms** trapped in optical lattices and manipulated using lasers. They offer excellent scalability and are being explored for large-scale quantum computing.

f) **Quantum Dots**: These are **nanoscale semiconductor structures** that trap single electrons. Their spin states act as qubits, and they are attractive for integration with existing semiconductor technologies.

g) **Topological Qubits**: These rely on **exotic quantum states** that are less affected by noise, making them more resistant to decoherence. They hold promise for building robust and fault-tolerant quantum computers.

h) **Majorana Qubits**: These are based on exotic particles called **Majorana fermions**, which are their own antiparticles. They are highly stable and resistant to errors, making them a promising candidate for **topological quantum computing**, where information is stored in the global properties of a system rather than individual qubits.

The Road Ahead

Despite its enormous potential, quantum computing is still in its early stages. Current quantum hardware suffers from **high error rates and short coherence times**, meaning qubits lose their quantum state quickly due to environmental interference. Researchers are actively working on **error correction techniques** and developing more stable qubit architectures, such as **topological qubits** and **Majorana fermions**, to build fault-tolerant quantum computers.

As quantum hardware advances, we may soon reach the era of **practical quantum advantage**, where quantum computers solve commercially valuable problems better than classical supercomputers. Companies like **Google, IBM, Intel, and startups like Rigetti and IonQ** are racing to develop scalable quantum processors, while governments worldwide are investing billions into quantum research.

Where Does India Stand in the Quantum Revolution?

India has set its sights on becoming a global player in quantum computing with the **National Quantum Mission (NQM)**, launched in 2023 with a budget of **₹6,000 crores**. This initiative is not just about keeping up with the world—it's about shaping the future. The mission aims to develop **quantum processors ranging**

from 50 to 1,000 qubits, build secure quantum communication networks, and advance research in quantum materials and sensing technologies. Leading institutions like **IISc, IITs, and national research labs** are already making strides in superconducting qubits, ion-trap systems, and quantum algorithms. With strong backing from **ISRO, DRDO, and industry partnerships**, India is laying the foundation for breakthroughs in **cyber security, artificial intelligence, and high-performance computing**. While challenges remain, the vision is clear: to not just participate in the global quantum race, but to lead in key areas and ensure technological independence for the future.

Quantum Computing Has Arrived; We Need to Prepare for Its Impact

Dr. Chuck Brooks

Global Thought Leader in Cyber security and Emerging Tech

Since the development of the electronic calculator in the 1960s, the field of computing has seen tremendous breakthroughs. In the field of information processing, the last several years have been particularly revolutionary. Technology has made what were previously considered science fiction dreams a reality. Our enabling equipment has become smaller and more versatile, and classical computing has become enormously quicker and more capable.

We are now moving into a new data era known as quantum computing, which is distinct from classical computing. By influencing the fields of artificial intelligence and data analytics, quantum computing is predicted to propel us into the future more quickly. The speed and power of quantum computing will enable us to tackle some of the most difficult problems that humanity has ever faced.

What is Quantum Computing?

Quantum computing is related to the enigmatic field of subatomic physics, which bases computations on states of uncertainty at the atomic level. Quantum computing draws on a fundamental concept of quantum physics known as "superposition," which means a single entity can occupy multiple states simultaneously. Quantum computing is defined by Gartner as "the use of atomic quantum states to effect computation." Qubits (quantum bits), which can store all conceivable states at once, are used to store data. Even when physically isolated, information stored in one qubit can influence data stored in another. This phenomenon is known as quantum entanglement.

In simpler terms, quantum computers employ quantum bits, or qubits, for digital communications rather than the conventional binary bits of ones and zeros. Since atoms are a physical system that may exist in both 0 and 1 states at the same time, they are used in quantum computers.

Recent Quantum Computing Advancements:

Scientific discoveries in quantum research during the last few years have been particularly revolutionary, leading to vastly faster and more accurate computers. Technological realities have replaced what were once considered science fiction fantasies.

Recently, the first wireless transmission of a quantum algorithm between two distinct quantum processors was accomplished by a group of researchers at the University of Oxford. Utilizing their unique nature, the two cores combined to create a powerful computer that could tackle issues that neither could handle on its own. By using quantum entanglement, the Oxford researchers were able to transmit basic data between computers almost instantly.

Additionally, quantum computing is becoming increasingly feasible thanks to recent advancements that make it simpler to build and more effective at scaling. The two main methods for quantum computing are the gate model and quantum annealing. Workable quantum solutions that make use of annealing systems are now in use. And gate models may arrive much faster than originally anticipated. In the past year alone, there have been some very impressive breakthroughs in both annealing and gate models:

Microsoft has recently advanced the timeline for the actualization of large-scale quantum computing. Their new Majorana 1 processor uses particles that are the opposite of each other. Microsoft uses depends on many electrons moving in synchrony as though they were a single particle. This method would enable qubits to be rapidly scaled for practical applications. The scope is enormous: one chip has the potential to surpass the combined performance of all current computers.

Google unveiled its strategy for quantum computing and unveiled Willow, its newest quantum chip with significant error-correcting enhancements. Willow can use more qubits to scale up and reduce errors. The development was dubbed a breakthrough by Google that will increase the dependability of quantum systems. For the past ten years, Google has been developing quantum chips. According to the company, its most recent Willow chip is so quick that it can finish a calculation in less than five minutes that would take a top-tier supercomputer today, such as the Frontier supercomputer in Tennessee, 10 septillion years, technically older than the universe itself.

Reimei, the first hybrid quantum supercomputer in history, has been turned on by Japanese engineers. The 20-qubit quantum machine has been integrated into Fugaku, the sixth-fastest supercomputer in the world. The hybrid computer used Quantinuum’s architecture.

Intel: In order to develop a fault-tolerant quantum computer, Intel is taking steps to build scalable silicon-based quantum processors, which pave the way for mass production and further scaling of silicon-based quantum processors. Intel’s latest work focuses on three key areas that are essential to the development of

quantum computing: high-volume testing, reproducibility, and qubit density. The silicon spin qubits produced by the company are smaller and denser than superconducting and trapped ion versions.

IBM recently created “IBM Quantum System Two" which is well-known for its quantum data centers. The modular quantum computer technology that IBM has introduced makes it simpler to scale and expand the capabilities of quantum computing. IBM made major hardware and software advancements to its quantum system; scientists say the company's latest quantum computer is now powerful enough for practical scientific study. IBM's newest 156-qubit quantum chip can run 50 times faster than its earlier version.

D-Wave Quantum. A major breakthrough in quantum computing has been made with the successful calibration and benchmarking of D-Wave Quantum's new 4,400+ qubit Advantage2TM processor. With the ability to solve issues 25,000 times faster and produce five times better results for high-precision jobs, the sixth-generation system outperforms its present AdvantageTM system in terms of performance. The processor demonstrated impressive performance in optimization, artificial intelligence, and materials science applications, outperforming the existing system in 99% of satisfiability problem testing.

Quantinuum recently Launched Industry-First, Trapped-Ion 56-Qubit Quantum Computer. An important milestone was achieved earlier last year that allows fault-tolerance was reached by Quantinuum's H-Series, which became the first to achieve "three 9s" – 99.9% – two-qubit gate fidelity across all qubit pairs in a production device. The development provides high fidelity to advance the field of quantum algorithms for industrial use cases broadly, and financial use cases in particular.

Small to midsize companies are making quantum breakthroughs too.

Quantum Computing Inc. runs a full-stack quantum solutions business to accelerate the delivery of hardware systems for quantum information processing that offer analytics and cybersecurity performance benefits. The advantage of quantum photonic computing is that it is operational and can be conducted at room temperature as the particles are more stable. QCI recently announced they are building their own photonic quantum computing chip at scale.

Rigetti Computing provides cloud access to their quantum computing systems via the “Forest” platform and creates superconducting qubit processors. Forest is made to enable programs that employ a quantum processor to provide traditional software new capabilities, similar to how a computer may have a graphics card. According to Rigetti, this hybrid architecture will be essential to making technology workable. Programmers can create quantum algorithms on the platform to simulate a 36-qubit quantum device.

IonQ creates software and computers for trapped ion quantum technology. The qubits of IonQ are ionized atoms of the silvery rare-earth element ytterbium. In the universe, every ytterbium atom is the same as every other ytterbium atom. They can be created in a certain stable quantum state and stay there for extended periods.

The Future of Quantum Technologies

Back in 2022, I had the privilege of speaking at the "Commercialising Quantum" conference, which was hosted by the editors of The Economist and focused on how businesses can get ready for the modern world.

My message was that we should be ready to invest to ensure that quantum capabilities for both national security and economic development are developed under the upcoming elements of quantum technologies.

Many now believe that the power and speed of quantum computing will enable us to address some of the biggest and most difficult problems our civilization faces. Problem-solving will be made possible by quantum computing’s unprecedented processing speed and predictive analytics. That is a remarkable near-term

potential. Mckinsey & Company forecasts that Quantum Technologies could create an economic value in the market of up to $2 Trillion by 2035. The Rise of Quantum Computing | McKinsey & Company.

Quantum measuring and sensing is one field where quantum technologies have already made their appearance. Navigational devices and magnetic resonance imaging (MRI) already employ it. Quantum sensors detect and quantify minute changes in time, gravity, temperature, pressure, rotation, acceleration, frequency, and magnetic and electric fields using the smallest amounts of matter and energy.

Quantum will have a direct impact on many scientific fields, including biology, chemistry, physics, and mathematics. Industry applications will have an impact on a wide range of fields, including healthcare, banking, communications, commerce, cybersecurity, energy, and space exploration. In other words, any sector in which data is a component.

More specifically, quantum technology has incredible potential to transform a wide range of fields, including materials science, lasers, biotechnology, communications, genetic sequencing, and real-time data analytics. Quantum computing is also expected to speed up the future via influencing the Metaverse and artificial intelligence landscape.

Quantum Cybersecurity

The success of quantum computing aligned with quantum supremacy can also pose risks. The United States and other nations are concerned that hackers are stealing data now so that it can be cracked by quantum computers within the decade. The same processing power that makes it possible to quickly decode or solve complicated problems can also be used to compromise cybersecurity. This directly threatens financial systems and other vital infrastructure.

It would take a billion years for a traditional computer to crack the encryption of today's RSA-2048 standard. It could theoretically break in less than two minutes if you had a functional quantum computer

An event referred to as Q-Day by quantum researchers is where large-scale quantum computers can use Shor's algorithm to break all public key systems that employ integer factorisation-based (and other) cryptography.

We are on the emerging pathway to the new era of quantum computing. And it is arriving in various forms sooner than we thought. Quantum technologies will inevitably be combined with artificial intelligence. The

implications of that convergence will be transformational. We must now prepare for the exponential benefits and risks of quantum technologies due to their potentially disruptive nature.

Resources for Quantum:

Below are some organizations that possess a wealth of information for a deeper dive into quantum topics.

Academia is also getting more involved in quantum research and development. In an important development,

to academia and industry as one of the nation's first publicly available testbeds for quantum security technology. The CQE's mission is" to lead the nation to an inclusive and sustainable quantum economy by connecting leading academic talent, top scientific facilities, and a diverse industry base that includes Fortune 500 companies, quantum startups, and a wide variety of sectors poised to adopt quantum technologies".

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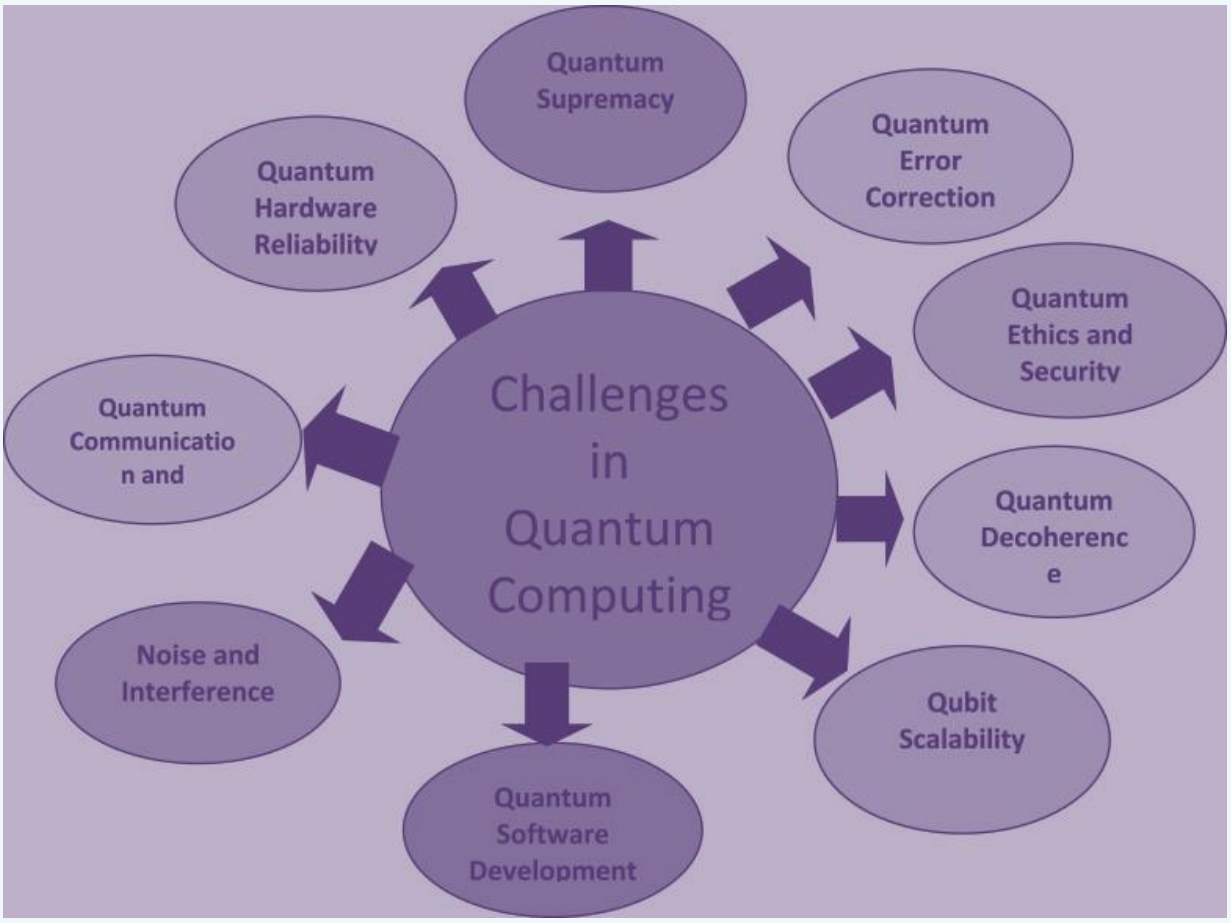

A quick look at how helicopters fly

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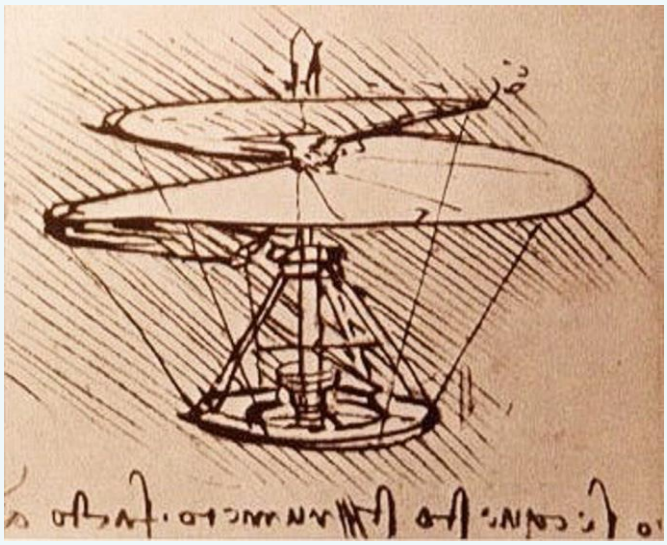
The idea for a vertically climbing spacecraft, that we now call a helicopter, has been around since the 15th-century when the celebrated Italian inventor and artist Leonardo da Vinci made sketches of an "aerial screw" proposed how it could fly.



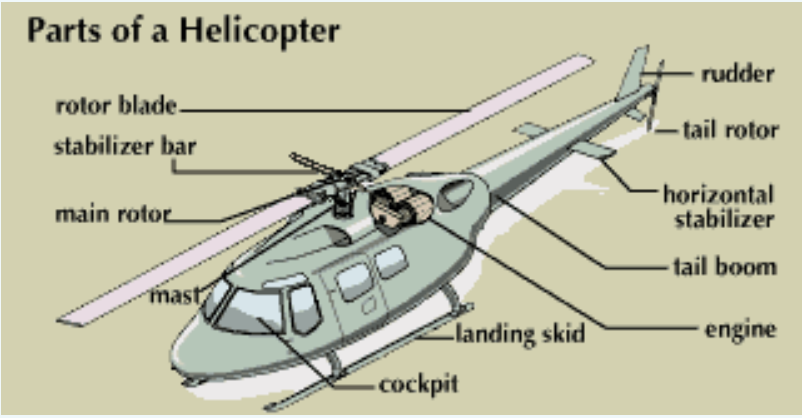
aerial screw' of Leonardo da Vinci

'Different theoretical designs were conceived and tried out over the following centuries by so many ingenious engineers, but that they did not work well. The first-generation working helicopters were built in the early 1900s around World War I. The early models were unstable and unreliable. It was only in 1939 that Igor Sikorsky finally produced the first truly functional and practical helicopter named the VS-300. He is rightly regarded as the 'father' of modern helicopters.

Unlike the fixed wing airplanes, designing and producing helicopters was difficult - learning how to fly them is equally challenging. It is fairly easy to see and understand how large, fixed and flat aerofoil shaped wings of an airplane moving through the air in the direction of travel generate lift. But a helicopter has to generate lift through specially designed rotating blades in place of wings and also move forward, backwards and sideways by orienting the plane of rotation of the rotating blades – all at the same time! Hence, helicopters are more complicated to fly and are inherently unstable compared to fixed wing aircraft.

The main parts of a helicopter

A helicopter has a light weight but sturdy metal body, called the fuselage, with a cockpit in the front and a long tail boom in the back. A high power rotary engine is placed on top of the fuselage. The fuel is kept underneath the seats. Rotating blades having aerofoil shape are attached to a central mast. A smaller set of rotary blades with aerofoil shape are attached near the end of what is called the tail boom for stability. Fixed



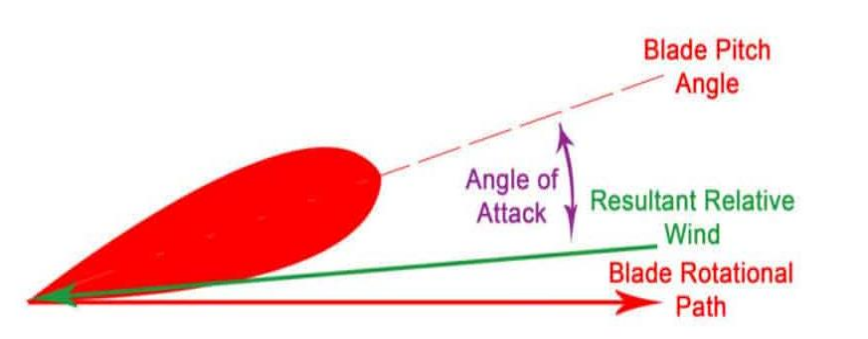
horizontal stabiliser and rudder can be there on the tail as shown in the figure. Horizontal stabiliser and the rudder are employed for stability. For safe landing of the fuselage, landing skids are attached to the lower side. Sometimes, the landing gear can have wheels for easy towing purpose .Of course, there are many more mechanical, electrical and electronic parts that are needed for its smooth operation and navigation.

Movements of a helicopter

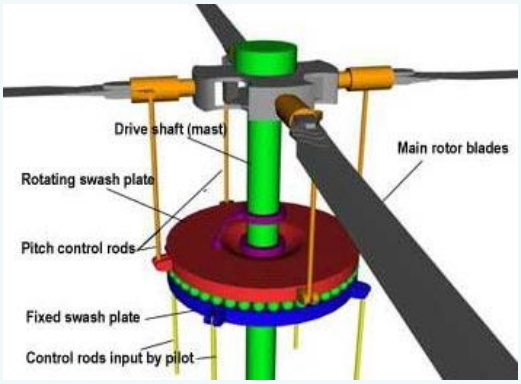
In a helicopter, lift force is generated by the airflow moving across the spinning rotor blades. Fixed wing planes must move down the runway to generate lift, but helicopters generate lift while remaining stationary with their main rotor blades. The main rotary blades have aerofoil shapes, like the wings of an airplane that produce lift force when they spin rapidly through the air around them.

Lift force can be controlled by adjusting their pitch (or the angle of attack) with the help of a lever called the collective stick. It is called a collective stick since it alters the pitch of all the blades at the same rate with the help of what is known as a rotating swash plate. It is an ingenious idea that is most essential for both vertical and horizontal motion.

When the lift force exceeds the total weight of the helicopter, the aircraft moves up. By exactly balancing the weight against the lift, it can stay at a particular height – such a motion is called hovering. The speed of the blades is controlled by a throttle attached to the collective controller stick similar to what one has in motor cycles.



Pitch angle of a blade



Fixed and rotating Swash plates

The collective controller lever which is usually placed on the left side of the pilot and it controls the pitch of the main rotor blades. Pitch changes are made collectively to all blades at the same time by moving it up or down. In practice, it is done by raising or lowering the top swash plate along the mast. When the pitch is high the lift increases. The pitch angle is reduced when the helicopter has to descend.

The helicopter's forward, backward, and side to side movements are controlled with the help of cyclic control stick (a joystick positioned between the pilot's legs). Like the collective, the cyclic control also adjusts the pitch of the main rotor blades, but instead of simultaneous adjustments, the cyclic

control inputs are made to each blade at the same point in its cycle. This is achieved by tilting the upper rotating swash plate with respect to the fixed bottom plate in the required direction. As a result, the pitch of rotary blades is changed when they arrive at a particular direction to produce motion in that direction in the horizontal plane. For forward motion, for example, the pitch of rotary blades is lowered on the front side causing a greater lift on the backside of the helicopter. Therefore, there will be a forward component to the total force on the helicopter in addition to the lift. Similarly, by tilting down the plane of the swash plate on the right side, the pitch of the blades is reduced on the right side, thereby producing a horizontal force towards the right side of the aircraft. Such small tilts of the upper swash plate are achieved with the help of a controller called a cyclic stick. The pilot operates it with his right hand. Hence, both his hands have to work simultaneously during a normal flight. The cyclic control stick -a joystick like lever – is positioned between the pilot's legs in the early model helicopters. It is an ingenious device that is crucial in horizontal helicopter motion. The bladed have to rotate and change their pitch while rotating - a complex operation indeed! More modern helicopters will be having a controller that can be operated by two pilots –and hence positioned between the two seats in the cockpit.

The tail rotor of the helicopter is very important for controlled flight. The tail rotor holds the helicopter straight and keeps it from spinning out of control in the opposite direction of the main rotor blades. The tail rotor blades also have aerofoil shape. Their pitch is controlled by foot pedals near the front of the cockpit. Unlike the main rotator, pitch angles of the tail rotor blade are changed collectively. Hence, yaw motion of the helicopter – turning motion about a vertical axis passing through the centre of gravity of the helicopter – are accomplished by pressing left or right foot pedals. Without the tail rotor blades, the helicopter fuselage would spin endlessly in a sense opposite to that of the main rotor blades!

Hence, a helicopter pilot has to keep both is hands and feet busy while flying the machine! Four controls have to manage six degrees of freedom – three translational and three rotational. Therefore, it is much more challenging than flying a fixed wing aircraft.

To fly a helicopter the pilot initially opens up the throttle to increase rotor speed. The main rotor blades spin until their rotation has reached a sufficient speed to generate lift. Once the main rotor is generating lift, the pilot slowly pulls up on the collective lever to simultaneously change the pitch of all rotor blades thereby making the helicopter to climb up.

Once a helicopter takes off, the pilot transitions from a hover to directional flight (forward, backward, and sideways) using cyclic inputs to tilt the rotor. The rotor tilt creates unbalanced lift and therefore thrust in the desired direction. Both the collective and cyclic levers have to work together for a smooth flight!

The cyclic lever is nudged in the intended direction of travel, causing the rotor blades to pitch lower in that direction. The increased angle of attack generates lift in the opposite direction, and the unbalanced lift lets the helicopter move in a lateral direction.

When a fixed wing plane is in straight and level flight, the airflow is the same across both wings. This equal airflow produces symmetrical lift. When it comes to helicopter aerodynamics, the blades are spinning in a circle as the aircraft moves forward, and there are advancing blades (moving into the direction of flight) and retreating rotor blades (moving away from the direction of flight).The advancing blades experience increased airflow and retreating blades have decreased airflow. This unmatched airflow causes a mismatch in lift generation, hence an asymmetric lift. Helicopters compensate for such asymmetric lift by what are called using blade flapping designs and cyclic feathering. Thus a helicopter is much more complicated! There are several other smaller effects that have to be taken care of.

Helicopters' maximum-altitudes are lower than fixed wing aircraft because as the air thins, rotor blade pitch needs to be increased to compensate the weight. There is only so much pitch adjustment that can be made due to blade design, and when pitch can no longer be adjusted, the helicopter can't generate lift. Normally helicopters can fly up to 10,000 feet only.

Unlike fixed wing planes, helicopters aren't built for extended flights and the average range of a helicopter is about 500 km depending on the size and type of helicopter. Specialised helicopters would have longer range.

However, helicopters become very essential in rescue missions, medical emergencies and military operations. So many advances have been incorporated in the modern helicopters over what has been described here. Helicopter designs have now given way to versatile drones with advances in technology.

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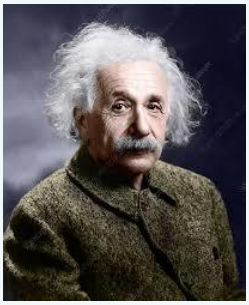

Selected Quotes from Albert Einstein

The Nobel laureate, who passed away in 1955, left behind numerous famous quotes. Here are a few that continue to inspire generations:

- "There are only two ways to live your life. One is as though nothing is a miracle. The other is as though everything is a miracle."
- "If you can't explain it to a six-year-old, you don't understand it yourself."
- "I am enough of an artist to draw freely upon my imagination. Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world."
- "Life is like riding a bicycle. To keep your balance, you must keep moving."
- "Anyone who has never made a mistake has never tried anything new."
- "Two things are infinite: the universe and human stupidity; and I'm not sure about the universe."
- "Science without religion is lame, religion without science is blind."
- "Any fool can know. The point is to understand."
- "Try not to become a man of success. Rather become a man of value."
- "The world as we have created it is a process of our thinking. It cannot be changed without changing our thinking."

P.A.M. Dirac – Life and Legacy

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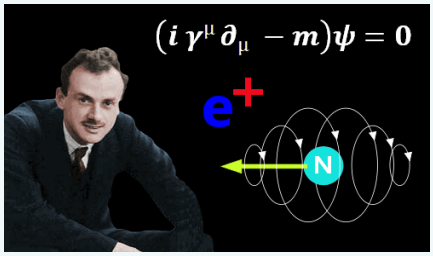


P.A.M. Dirac was one of the greatest theoretical physicists in history. He completely reshaped quantum mechanics establishing **Quantum Electrodynamics**, the surprisingly impressive **Dirac Equation** which explains the behaviour of electrons and predicts the existence of **antimatter** accounting for the creation and annihilation of photons of light within atoms.

Beginnings

P.A.M Dirac was born in the city of Bristol, England, UK on August 8, 1902. His father was Charles Dirac, a school teacher and private tutor who had emigrated from Switzerland to the UK. His mother was Florence Holten, a former librarian. She was named after Florence Nightingale. At the age 12, he started high school in Merchant Venturers' Technical College, where his father taught French.

University of Bristol

In September 1918, at the age of 16, Dirac began a degree course in electrical engineering at the University of Bristol and graduated with first class honors in 1921. His mathematical talents were extraordinary. He continued his study for another two years at the same university to get first class honors degree in mathematics.

University of Cambridge

In 1923, he joined graduate school at Cambridge, where he carried out research in general relativity and quantum mechanics. His doctoral advisor, Ralph Fowler, a mathematical physicist, introduced Dirac to the new atomic model of Niels Bohr. By the end of 1924, Dirac had completely mastered quantum theory and obtained his doctorate degree at the start of 1927.

Later he spent for a short time, working at the world's centres of quantum mechanics, Copenhagen (Denmark) and Gottingen (Germany).

Dirac Develops Quantum Electrodynamics

Quantum electrodynamics often abbreviated to QED describes the quantum interaction of light and matter. Dirac launched QED with his 1927 paper "The Quantum Theory of the Emission and Absorption of Radiation". His new theory unified the previously separate phenomena of the light-wave and the light-quantum. It was the first theory that dealt successfully with the fact that when an atom absorbs a photon, the

light disappears from the universe; and when an atom releases light, a photon appears in the universe. No theory before had accounted for the creation and annihilation of quantum objects such as photons. Dirac pictured universe in which atoms contain an infinite supply of zero-energy photons available for release as real photons if energy is supplied to them

Dirac Equation

Back in Cambridge, in October 1927, Dirac focused with dedication on electron behaviour. Heisenberg and Schrödinger's quantum mechanics worked perfectly well for slow moving electrons, but failed for electrons traveling at substantial fractions of the speed of light. Dirac now sought to combine quantum mechanics with Einstein's special theory of relativity to create the theory of electrons. He began with Schrödinger's wave equation, incorporated matrices and relativity, treating time as a quantum variable. Gradually, he persuaded the gloomy and uncertain quantum world to reveal a mathematical description of the electron. By the beginning of December 1927, he created the following beautiful and powerful fundamental Dirac Equation of the relativistic theory of the electron

$$(i\,\gamma^{\mu}\,\partial_{\mu} - m)\psi = 0$$

In early February 1928, Dirac's paper "The Quantum Theory of the Electron" was published by the Royal Society. Physicists all over the world admired his achievements and regarded as one of the greatest physics papers ever written, because it accounted naturally for the electron's spin, a mystery since experimenters discovered it three years before. In 1930, Dirac completed his book: The Principles of Quantum Mechanics. For students of the subject, it became the essential work.

Prediction of anti-matter

In September 1931, he published a paper, in which he predicts the existence of anti-matter. His equation not only works for an electron with negative charge, it also works for a particle that behaves like an electron with positive charge. At first, Dirac did not appreciate the significance of this finding and even ignored it out of what he would call "pure cowardice".

Eventually, he realised that his equation predicts something entirely new to science – **antiparticle**. He went on to assert that every particle has a mirror-imaged antiparticle with nearly identical properties, except for an opposite electric charge. Just as protons, neutrons and electrons combine to form atoms and matter, antiprotons, antineutrons and anti-electrons (called positrons) combine to form anti-atoms and antimatter. His findings led him to speculate that there may even be a mirror universe of antimatter. In 1932, Carl Anderson at the California Institute of Technology discovered Dirac's positively charged electron in cloud chamber experiments. Dirac's anti-electron is now called the positron. This unknown and strange particle first seen in the mathematical symbols of Dirac's equation turned out to be a real particle which is so real that today, it is utilized in hospitals to detect cancers through positron emission tomography. Anti-particle application in accelerator physics enabled the design of the **Large Hadron Collider** at **CERN** which contributed to the discovery of some new particles, in particular the **bosons** of the weak interaction.

Cambridge's Lucasian Chair of Mathematics

Dirac was appointed to Cambridge's Lucasian Chair of Mathematics, once held by Isaac Newton three centuries ago. He was one of the greatest scientists of the 20th century, a pioneer in the field of theoretical

physics whose name is often mentioned in the same breath as those of **Isaac Newton** and **Albert Einstein**. Dirac's annual lecture course at Cambridge became legendary. Between 1930 and 1933, **Subrahmanyan Chandrasekhar** attended it four times, recalling that it: "was just like a piece of music you want to hear over and over again."

Nobel Prize

Dirac and Schrödinger shared the 1933 Nobel Prize in Physics, "for the discovery of new productive forms of atomic theory."

Association with Institute for advanced Study, USA:

In 1931, Dirac had been invited to Princeton University, USA by Ostwald Veblen, then a Professor at the University. In 1932, aged 30, , After the World War II, he accepted an offer from his old friend, **J. Robert Oppenheimer**, newly appointed Director of the Institute for advanced Study (IAS), USA, to spend a sabbatical there in the 1947–48 academic year. Having been assured by Oppenheimer of a permanent welcome at the Institute, Dirac stayed there many times during the next eighteen years.

Association with Florida State University, USA

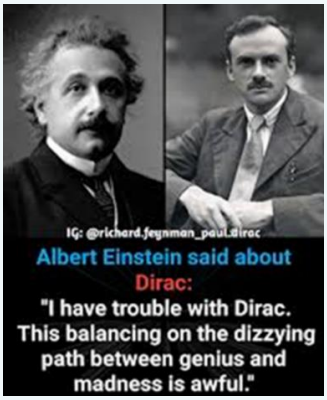
He spent the last 14 years of his life teaching at Florida State University, USA until his death in 1984."Although he was one of Einstein's most admired colleagues, Dirac isn't a household name, the way Einstein is, and that's unfortunate," said Mark Riley, Chairman of the Department of Physics at Florida State. "However 100 years, even 500 years from now, Dirac will be remembered alongside Einstein as one of the greatest scientific minds in human history. "Dirac's legacy lives on at Florida State. The Paul A.M. Dirac Science Library bears his name, as do two named professorships, one in the Department of Physics and the other in the Department of Chemistry and Biochemistry.

Dirac with Robert Oppenheimer and Abraham Pais, 1947

Dirac worked with several legendries:

Dirac worked with several legendries such as **Niels Bohr, Albert Einstein**, and **Oswald Veblen**. Dirac worked hard on weekdays but reserved weekends for family and for socializing with his colleagues (his elder daughter long remembered having tea one Sunday with the Einstein household). To seek help on quantum problem, Albert Einstein would cry out, "Where's my Dirac?" Dirac's final visit to IAS had been in 1979, when he attended the symposium to mark the centenary of Einstein's birth.

Some pictures related to Dirac:



[Memorial of Dirac , his wife & daughter Mary, Tallahassee, Florida.]

Dirac and Pauli, 1948

Dirac with Feynman

[Dirac, Heisenberg and Schrodinger at the Nobel Prize award ceremony, 1933]

Alan Turing – Life and Achievements

Yash Hoskere

Data Scientist
with Perfios Software Solutions, Mumbai

Introduction: How fascinating it is to realize that a certain category of work that required long hours for completion only a few decades ago can be completed within seconds now, all thanks to the power of computation. The modern world, indeed, is incomplete and unimaginable without computers. However, this idea was conceived long before the first modern day computer became a reality. From Napier's (1550 - 1617) *Bones* to Pascal's (1623 - 1662) *Adding Machines* to Leibnitz's (1646 - 1716) *Stepper Reckoner*, all tried to create a machine which would perform the calculations done by humans. It was only the *difference engine* and *analytical engine* conceived by Charles Babbage (1791 - 1871) that resulted in the first big step towards inventing a complex computing machine. The possibility of an intelligent computer was first suggested by a young English Mathematician, Alan Turing (1912 - 1954), in a paper titled *On Computable Numbers, with an Application to the Entscheidungs problem*, published in the Proceedings of the London Mathematical Society Journal in 1936. The paper referred to a hypothetical machine which, later, came to be known as the Turing Machine named after Turing himself. This article attempts to elucidate and highlight Turing's revolutionary contribution.

However, before the Second World War the word, 'computer' meant a person, often a woman, who did calculations either manually or with the help of a mechanically adding machine, but not the present-day computer. These human computers performed fast calculations which were often repetitive in nature, such as those necessary for the creation of books of log tables. This is the background.

Figure 1(a) Napier's Bones

Figure 2(b) Leibnitz machine

Figure 4(c) Pascaline

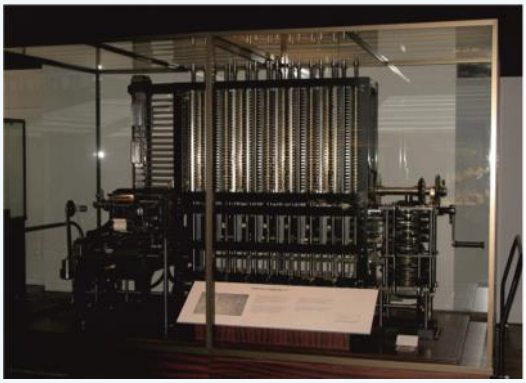


Figure 3(d) Babbage Difference Engine

Mathematics as a Formal System: If I ask you what physics is, the most common reply would be; it is the study of motion and behaviour of matter in space and time to understand how the universe behaves. If I ask what chemistry is, the reply would be; it is the study of molecules and their interactions. However, if you ask what mathematics is, you will get different answers which may or may not be satisfactory. One of the main reasons is that mathematics does not have a generally accepted definition.

Figure 5: David Hilbert

It was due to this confusion that in the beginning of the twentieth century many mathematicians began to ask serious questions regarding the nature of the subject. Ancient Greek philosopher, Plato (427 – 347 B. C. E.) argued that mathematics has a very different dimension and called it 'The World of Forms'. Immanuel Kant (1724 – 1804 C. E.), a German philosopher, maintained that mathematics is an outcome of our intuition. He was followed by another great German mathematician, David Hilbert (1862 - 1943). He proposed a project which, he thought, would revolutionise mathematical thinking. Hilbert wanted to formalize mathematics. A system that consists of symbols and follows some predefined rules within a given environment and does not have any meaning outside the given environment is called a formal system. Chess is a very good example a formal system. The pieces on the board have some meaning and the same pieces have no meaning outside the board.

Hilbert posed three questions at an international conference in 1928. Out of the three questions that Hilbert posed one is *Entscheidungs* problem, meaning decision problem, which was mentioned above. A decision problem is the one which can be answered with 'yes' or 'no'. the problem asks for an algorithm that considers a statement as an input and an answer, 'Yes' or 'No' depending on whether or not the statement universally holds good. A better way to put it is; is mathematics decidable?

Turing's Machine: Alan Turing, then just 24, showed keen interest in the decision problem posed by Hilbert. In his paper (1936), Turing proposed an abstract machine, now called the Turing machine, which moved from one state to another using a precise and finite set of rules. Although for Turing a computer was a person who carried out a computation, he decided to lay down the rules for this machine which closely mirrored the rules that human computers followed.

1. Just as a human computer needed to find an answer to a given problem, the machine also is required to find an answer to a given problem statement.

2. The limits and the boundaries of the question will be well defined.
3. As a human computer uses sheets of paper to work on, the machine uses tape on which it can write.
4. A human computer uses a pen and eraser to write and erase, as the case may be. Similarly, a machine gets the ability to write one symbol at one time and erase one symbol at a time.
5. Just as human hands can move, the machine head also can move from left to write or right to left freely and the tape would consist of the pre-fed problem. To visualise this better, see fig. 3.

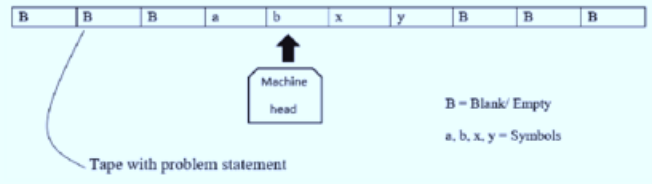


Figure 6: Illustration of a Hypothetical Turing Machine

Now each Turing machine is guided by a set of states through which it passes on every symbol it sees and the decision it makes. Here is a state diagram which shows a Turing machine designed to do comparison of two strings.

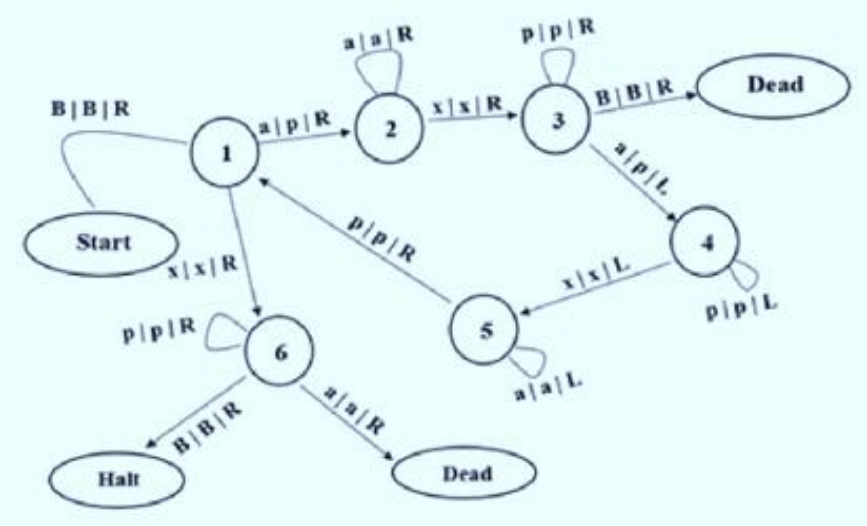


Figure 4: State Diagram of a Turing Machine which performs comparison of two strings.

You can observe that there are some symbols on the state diagram. These are the conditions for the Turing machine to check before making a move to the next state. The format of the symbol is like

current symbol l replacing symbol l head movement direction

we shall consider a question to understand this better. Here is a problem statement where B is a blank space, ‘a’ is the symbol and ‘x’ separates two strings. Here we are comparing ‘aa’ with ‘aa’. Let us see how the Turing machine computes the two strings and tell whether both are the same or different. The

head starts from blank space. I have shown the process on a tape with an arrow indicating the head of the Turing machine.

B	a	A	X	a	a	B

↑

1. Look at the state diagram. You see a state called 'start'. Our machine begins from here.
2. So, the condition for it to move to state 1 is 'B|B|R' (blank symbol | replace it with blank itself | move right). The head is currently looking at a blank cell. You can see this in the tape above. After the condition is read and executed you will see a tape

B	a	A	X	A	a	B

↑

3. The head is seeing 'a' and the condition on state1 is a|p|R (see 'a' on the cell | replace it with p | move right) which is satisfied. Move to state 2. You can see the tape below. Now you might have got a fair idea of how to read the condition.

B	p	A	X	a	a	B

↑

4. On state 2 you have two conditions, 'a|a|R' here. You should remain on state 2 itself as there is a loop on this condition.

B	p	a	X	a	a	B

↑

5. 'X|X|R' is satisfied; moves on to state 3.

B	p	a	X	a	a	B

↑

6. Of three conditions on state 3, 'a|p|L' is the right match.

B	p	a	X	p	a	B

7. 'X|X|L on state 4.

B	p	a	X	p	a	B

↑

8. 'a|a|L on state 5 remains on state 5.

B	p	a	X	p	a	B

↑

9. P|P|R on state 5 and moves to state1.

B	p	a	X	p	a	B

↑

10. The same process is repeated once on state 1 ‘a|p|R’ and moves to state 2.

B	p	P	X	p	A	B

↑

11. X|X|R’ on state 2 and moves to state 3.

B	p	p	X	p	a	B

↑

12. ‘p|p|R’ on state 3 and will remain on state 3.

B	p	p	X	p	a	B

↑

13. ‘a|p|L on state 3 and moves to state 4.

B	p	p	X	p	p	B

↑

14. ‘p|p|L’ on state 4 and will remain on state 4.

B	p	p	X	p	p	B

↑

15. ‘X|X|L’ on state 4 and moves to state 5.

B	p	p	X	p	p	B

↑

16. ‘p|p|R’ on state 5 and moves to state 1.

B	p	p	X	p	a	B

17. ‘X|X|R’ on state 1 takes you to state 6 and on state 6 we keep repeating ‘p|p|R’. If we encounter a symbol ‘a’, then it means that the right side string has more ‘a’ and the machine will enter a dead state which means ‘reject’ and two strings are not the same. But, here, as we move right, we encounter ‘B’ which is blank meaning all the symbols have been seen. Hence the move to halt state means that the strings are the same.

You can also observe that on state 3 there is another dead state and that is to check whether the left side is a larger string among the two. Also, we are renaming the symbols to make it easier to differentiate the symbols that are checked and not checked by the head. Likewise, we can create a Turing machine for

addition and subtraction also. A machine that can perform addition, subtraction and comparison can also perform any mathematical calculation, however complex it may be. The Turing machine is considered to be one of the most powerful theoretical computers ever designed. Even with all the advancement in technology, there is not a single problem that a present generation computer can solve which the Turing machine cannot. One may also argue that modern computer is much faster whereas the time consumed to design a state diagram is too much and further, walking through each state can be a tedious task even for comparing two strings of length 2. However, if we ignore this aspect, then the Turing machine can virtually solve every mathematical problem that a super computer can.

Shortly before Alan Turing published his theoretical machine, another mathematician, Alonzo Church (1903 - 1995) published his solution to the decision problem titled 'Lambda Calculus'. Church effectively demonstrated that both the Turing machine and Lambda Calculus were equivalent in power, but it is the Turing machine which is much more widely studied today due to its simple design and working compared to a very complex Lambda Calculus.

With the help of the Turing machine, Turing also effectively demonstrated that a solution to a decision problem is undecidable in first order logic demanding true or false answer.

Turing used a method called proof by contradiction to show that the decision problem is undecidable. As Hilbert wanted an algorithm and the state diagram, what we just studied is nothing but an algorithm due to its step-by-step process to reach an answer. So, the original decision problem statement can be redesigned now as, 'can there be a Turing machine which can decide the outcome of another Turing machine in the form of true (halt) or false (runs forever)'? Turing assumed that such a Turing machine does not exist. Let us call it Dave which runs on a state diagram on its own. The figure below shows a box called Dave which has an input question and an output as halt or run forever. Halt means that the machine has arrived at a decision. So, it stops; and runs forever means that the machine cannot decide and so keeps on running. Bear in mind that each one of these Turing machines has its own state diagram, based on which they are making decisions and for the sake of simplicity we represent them as boxes.

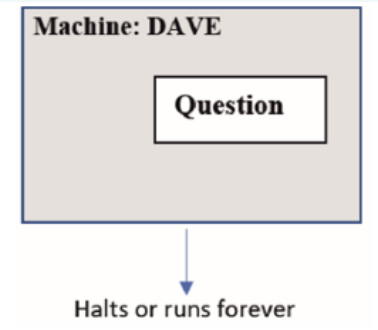


Fig 5: Turing Machine called Daves with its output

If you give a statement to Dave, it will predict whether it will halt (true) or will run forever (false). The above figure represents machine Dave which, when given an input, outputs whether it will halt or run forever. Let us consider another Turing machine called John. In the figure below you can see John displayed as a box which contains Dave. Dave's output is taken as

John's input and based on that John decides the output. John is configured to do the opposite of what Dave outputs. So, if Dave says statement 'x' is false, John will say it is true and if Dave says the statement 'x' is true, John will say it is false.

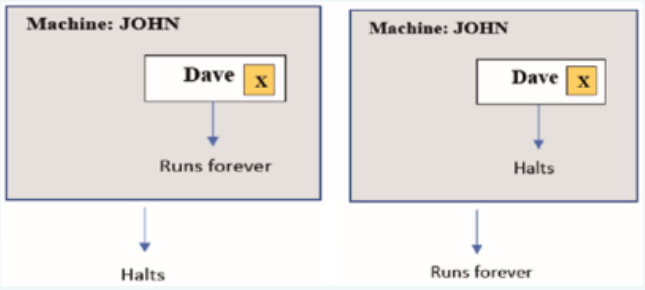


Fig 6: Turing called John where the output is the output of Dave

What will happen if you ask Dave itself to predict what Dave is going to output? Let us say we have two Daves, identical in function, but have different names. One is First-Dave and the other is Second-Dave. If you ask First-Dave, 'is the reader of this article male', First-Dave may say true or may say false and if you ask second-Dave, 'what will be the First-Dave output', it will be the same as that of First-Dave as both of them are the same. Similarly, if you ask John to predict what another John will output, again, it will be the same. It is like predicting what you will say which is always the same. This is where the genius of Turing can be seen. He asked John what Dave will output by first asking Dave what John will output. Look at the figure below to understand logic better. The question to Dave is; what will John output?

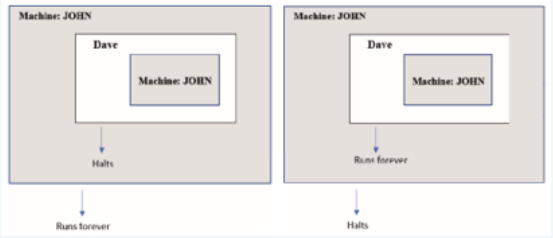


Fig 7: John given as input to John itself

Look at the figure 8; first Dave is given John as an input and Dave gives an output. Then John has to predict what Dave will output. If Dave says John will say true (halts), then John will say false (run forever) because John tells the opposite of Dave. But this is a contradiction because Dave said that John will say true, but now John itself is predicting that John will say false. Similarly, if Dave says John will say false, then John will predict true as the outcome of Dave which is that of John itself. Thus, by showing one example where the machine fails, Turing proved that there cannot be a universal algorithm which can predict the outcome of another algorithm and concluded that mathematics is undecidable. It means that it is impossible to construct an algorithm which can always lead to a decisive 'yes' or 'no' answer.

The philosophical aspect of this proof is quite significant. If we go essentially by the logic of this proof, then it means that there may be questions pertaining to the universe which cannot be answered with decisive 'yes' or 'no'. Questions such as - *is there God*; *is the universe finite*; *is*

time travel possible – may not have a first order logic answer in the sense of simple 'yes' or 'no'. Turing's ingenuity can be imagined by his discovery of a computer even before it was built. However, Turing's biggest achievement was decrypting "The Enigma machine" used by the Nazi Germany under the Hitler during World War II. This changed the course of war leading to the victory of the Allied forces over Hitler and saved millions of lives.

Turing introduced many central concepts of Artificial Intelligence (AI) in a report titled "Intelligent Machinery" in 1948. He said; what we want is a machine that can learn from experience", and that the "possibility of letting the machine alter its own instructions provides the mechanism for this". Turing introduced a practical test for computer intelligence in 1950 that is now simply known as the Turing test. This test involves three participants: a computer, a human interrogator and a human participant. the interrogator attempts to determine, by putting questions to the other two participants, which one is the computer. All communication is via keyboard and display screen. If the Interrogator fails to identify which one Is human and which one is computer, then the computer is considered intelligent. I am quite sure we are already there.

Turing also had an Indian connect. His father, Julius Mathison Turing was an officer with the Indian Civil Service (ICS) at Chhatarpur in Odisha state (then in Madras Presidency). Turing's mother was Ethel Sara Turing, a daughter of Edward Waller Stoney, the Chief Engineer of then Madras Railways.

Ending on a humorous note: construct a Turing machine following the same line and ask, 'Am I smart; true or false?

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Alan M. Turing Quotes

We can only see a short distance ahead, but we can see plenty there that needs to be done.

If a machine is expected to be infallible, it cannot also be intelligent.

Sometimes it is the people who no one imagines anything of who do the things that no one can imagine

The original question, 'Can machines think?' I believe to be too meaningless to deserve discussion.

Why even physicists still don't understand quantum theory 100 years on?

Dr. Sean Carroll

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Everyone has their favourite example of a trick that reliably gets a certain job done, even if they don't really understand why. Back in the day, it might have been slapping the top of your television set when the picture went fuzzy. Today, it might be turning your computer off and on again. Quantum mechanics — the most successful and important theory in modern physics — is like that. It works wonderfully, explaining things from lasers and chemistry to the Higgs boson and the stability of matter. But physicists don't know why. Or at least, if some of us think we know why, most others don't agree.

How quantum mechanics emerged in a few revolutionary months 100 years ago

The singular feature of quantum theory is that the way we describe physical systems is distinct from what we see when we observe them. The textbook rules of quantum mechanics therefore need to invoke special processes to describe 'measurement' or 'observation', unlike every previous framework for physics. As a field, physics does not have any consensus on why that is the case, or what it even means.

Werner Heisenberg

The first hints of quantum behaviour in nature came in works by physicists Max Planck in 1900 and Albert Einstein in 1905. They showed that certain properties of light could best be explained by imagining that it came in discrete, particle-like chunks, rather than as the smooth waves that classical electromagnetism depicts. But their ideas fell short of describing a complete theory.

It was the German physicist Werner Heisenberg who, in 1925, first put forward a comprehensive version of quantum mechanics. Later that year, Max Born and Pascal Jordan followed up on that with Heisenberg, and Erwin Schrödinger soon produced an independent formulation of the theory[1]

So it is fair to celebrate 2025 as the true centenary of quantum theory. Although such a commemoration can rightly point to a wide variety of breath taking experimental successes, it must leave room to acknowledge the foundational questions that remain unanswered. Quantum mechanics is a beautiful castle, and it would be nice to be reassured that it is not built on sand.

Break from the past

Ever since Isaac Newton formulated classical mechanics in the seventeenth century, theories of physics have followed a definite pattern. You have a system under consideration: perhaps a planet orbiting a star, or an

electric field or a box of gas. At any one moment in time, the system is described by its 'state', which includes both the system's current configuration and its rate of change; for a featureless single particle, this amounts to its position and velocity (or, equivalently, momentum). Then, you have equations of motion, which tell us how the system will evolve, given its present state. This basic recipe worked for everything from Newtonian gravity right up to Einstein's theories of relativity, which, like quantum theory, are a product of the early twentieth century. But with the advent of quantum mechanics, the recipe suddenly failed.

The failure of the classical paradigm can be traced to a single, provocative concept: measurement. The importance of the idea and practice of measurement has been acknowledged by working scientists as long as there have been working scientists. But in pre-quantum theories, the basic concept was taken for granted. Whatever physically real quantities a theory postulated were assumed to have some specific values in any particular situation. If you wanted to, you could go and measure them. If you were a sloppy experimentalist, you might have significant measurement errors, or disturb the system while measuring it, but these weren't ineluctable features of physics itself. By trying harder, you could measure things as delicately and precisely as you wished, at least as far as the laws of physics were concerned.

Quantum mechanics tells a very different story. Whereas in classical physics, a particle such as an electron has a real, objective position and momentum at any given moment, in quantum mechanics, those quantities don't, in general, 'exist' in any objective way before that measurement. Position and momentum are things that can be observed, but they are not pre-existing facts. That is quite a distinction. The most vivid implication of this situation is Heisenberg's uncertainty principle, introduced in 1927, which says that there is no state an electron can be in for which we can perfectly predict both its position and its momentum ahead of time2.

Erwin Schrodinger

Instead, quantum theory describes the state of a system in terms of a wave function, a concept introduced3 by Schrödinger in 1926, together with his eponymous equation that describes how the system changes over time. For our single electron, the wave function is a number assigned to every position we might observe the electron to be in — a wave, in other words, that might be mostly localized near an atomic nucleus or spread widely throughout space.

Where things get tricky is in the relationship between the wave function and observable quantities, such as position and momentum that we might want to measure. The answer was suggested4 by Born soon after Schrödinger's original paper. According to Born's interpretation, we can never precisely predict the outcome of a quantum measurement. Instead, we can determine the probability of getting any particular outcome for an electron's position, say, by calculating the square of the wave function at that position. This recipe completely overturned the ideal of a deterministic, clockwork universe that had held sway since Newton's time.

In retrospect, it is impressive how quickly some physicists were able to accept this shift. Some, not all. Luminaries such as Einstein and Schrödinger were unsatisfied with the new quantum consensus. It's not that they didn't understand it, but that they thought the new rules must be stepping stones to an even more comprehensive theory.

The appearance of indeterminism is often depicted as their major objection to quantum theory — "God doesn't play dice with the Universe", in Einstein's memorable phrase. But the real worries ran deeper.

Einstein in particular cared about locality, the idea that the world consists of things existing at specific locations in space-time, interacting directly with nearby things. He was also concerned about realism, the idea that the concepts in physics map onto truly existing features of the world, rather than being mere calculational conveniences.

Einstein's sharpest critique appeared in the famous EPR paper5 of 1935 — named after him and his co-authors Boris Podolsky and Nathan Rosen — with the title 'can quantum-mechanical description of physical reality be considered complete?'. The authors answered this question in the negative, on the basis of a crucial quantum phenomenon they highlighted that became known as entanglement.

If we have a single particle, the wave function assigns a number to every possible position it might have. According to Born's rule, the probability of observing that position is the square of the number. But if we have two particles, we don't have two wave functions; quantum mechanics gives a single number to every possible simultaneous configuration of the two-particle system. As we consider larger and larger systems, they continue to be described by a single wave function, all the way up to the wave function of the entire Universe.

As a result, the probability of observing one particle to be somewhere can depend on where we observe another particle to be, and this remains true no matter how far apart they are. The EPR analysis shows that we could have one particle here on Earth and another on a planet light years away, and our prediction for what we would measure about the faraway particle could be 'immediately' affected by what we measure about the nearby particle.

The scare quotes serve to remind us that, according to the special theory of relativity, even the concept of 'at the same time' isn't well defined for points far apart in space, as Einstein knew better than anyone. Entanglement seems to go against the precepts of special relativity by implying that information travels faster than light — how else can the distant particle 'know' that we have just performed a measurement?

We can't actually use entanglement to communicate across great distances. Measuring our quantum particle here, we now know something about what will be observed far away, but anyone who is actually far away doesn't have access to the knowledge we have, so no communication has occurred. But there is at least a certain tension between how quantum theory describes the world and how we think space-time works in Einsteinian relativity.

Reclaiming reality

Attempts to resolve this tension have proliferated, with no clear consensus in sight. Indeed, significant disagreement lingers around the most central question we can think of: is the quantum wave function supposed to represent reality, or is it just a tool we use to calculate the probability of experimental outcomes?

Bohr and Einstein

This issue fundamentally divided Einstein and the Danish physicist Niels Bohr in famous debates they had over decades about the meaning of quantum mechanics. Einstein, like

Schrödinger, was a thoroughgoing realist: he wanted his theories to describe something we might recognize as physical reality. Bohr, along with Heisenberg, was willing to forgo any talk about what was 'really happening', focusing instead on making predictions for what will happen when something is measured.
The latter perspective gave rise to 'epistemic' interpretations of quantum theory. The views of Bohr and Heisenberg came to be known as the Copenhagen interpretation, which is very close to what physicists teach in textbooks today. Modern versions include QBism6, short for 'quantum Bayesianism', and relational quantum mechanics7. Both of these interpretations emphasize how quantum states shouldn't be considered in their own right, but only relative to an observer, the process of measuring and the changing states of knowledge during that process.

A nice thing about epistemic approaches is that worries about faster-than-light influences evaporate. When an observer takes a measurement, they update their knowledge; nothing physically travels from one entangled particle to another. A downside is that these approaches completely leave open the question of what reality truly is, which is (or should be, one presumes) important to physics. This is especially problematic given that the wave function certainly acts like a physical thing under certain circumstances. For example, the wave function can interfere with itself, as demonstrated in the double-slit experiment. A wave function that passes through two narrow slits, recombining on the other side, will constructively or destructively interfere depending on the oscillations of the wave. That certainly sounds like the behaviour of a real physical thing.

The alternative is an ontic approach, accepting that the quantum state represents reality (at least in part). The problem there is that we never 'see' the wave function itself; we only use it to make predictions for what we do see. We can think of the wave function as representing a superposition of many possible measurement outcomes. But is hard to resist, once we have made a measurement and recorded an outcome, thinking of that result as what is real, not the abstract superposition of possibilities that preceded it.

There are a number of ontic models of quantum mechanics that reconcile the centrality of wave functions with their tricky relationship to observations. In pilot-wave or hidden-variable models, first developed comprehensively8,9 by David Bohm in the early 1950s, wave functions are real but there are also extra degrees of freedom representing the actual positions of particles, and it is the latter that get observed.


Hugh Everett

In the Everettian, or many-worlds, interpretation, introduced by Hugh Everett a little later10, observers become entangled with the systems they measure, and every allowed outcome is realized in separate branches of the wave function, which are interpreted as parallel worlds. In objective-collapse models of varying flavours11,12, the wave function occasionally adjusts itself (in violation of the conventional Schrödinger equation) to look like the semi classical reality we observe.

Does quantum theory imply the entire Universe is preordained?

Although these approaches are often thought of as competing interpretations of quantum mechanics, this is a misconception, because they are distinct physical theories. Objective-collapse models have a variety of explicit experimental consequences; most dramatically, by violating the principle of energy conservation when the wave function objectively collapses, something that might be observable in

ultra-cold atomic systems. Tests are ongoing, but no evidence for these effects has yet been found. As far as anyone knows, there is no experiment that could distinguish between pilot-wave and Everettian approaches. (Advocates of each tend to argue that the other is simply ill defined.)

So, physicists don't agree on what precisely a measurement is, whether wave functions represent physical reality, whether there are physical variables in addition to the wave function or whether the wave function always obeys the Schrödinger equation. Despite all this, modern quantum mechanics has given us some of the most precisely tested predictions in all of science, with agreement between theory and experiment stretching to many decimal places.

The theory of relativistic quantum fields, the basis of all of modern particle physics, must count among the greatest successes of quantum mechanics. To accommodate the observed fact that particles can be created or destroyed, along with the symmetries of relativity, its starting point is quantum fields stretching through all of space. The rules of quantum theory imply that small vibrations in such fields naturally seem to be collections of individual particles. The iterated influences of these vibrations on each other lead to a plethora of observable phenomena that have fantastically been confirmed by experiment, from how quarks are confined to make protons and neutrons, to the existence of the Higgs boson. This particle arises from vibrations in a Higgs field suffusing all of space, which gives mass to other particles and explains why the weak nuclear force has such a short range. According to the cosmological inflation theory, the origin of stars and galaxies might even be traced to tiny quantum variations in the density of the early Universe.

But for all its successes, quantum field theory has its own puzzles. Infamously, a straightforward calculation of the quantum corrections to the scattering probability of two particles often results in infinitely large answers — not a feature you want a probability to have. Modern physics has come to terms with this issue by using 'effective field theories', which attempt to describe processes only at (relatively) low energies and momenta, and from which the troublesome infinities are entirely absent.

Einstein, Bohr and the war over quantum theory

But this framework still leaves us with problems of 'naturalness'. In the effective-field-theory approach, parameters we observe at low energies represent the combined effects of unobservable processes at very high energies. This understanding allows us to predict what natural values should be for parameters such as the Higgs mass or the energy density of the vacuum. But the observed values of these numbers are much lower than expected — a problem that still awaits convincing solution.

Then, there is the largest problem of all: the difficulty of constructing a fundamental quantum theory of gravity and curved space-time. Most researchers in the field imagine that quantum mechanics itself does not need any modification; we simply need to work out how to fit curved space-time into the story in a consistent way. But we seem to be far away from this goal.

Meanwhile, the myriad manifestations of quantum theory continue to find application in an increasing number of relatively down-to-Earth technologies. Quantum chemistry is opening avenues in the design of advanced pharmaceuticals, exotic materials and energy storage. Quantum metrology and sensing are enabling measurements of physical quantities with unprecedented precision, up to and including the detection

of the tiny rocking of a pendulum caused by a passing gravitational wave generated by black holes one billion light-years away. And of course, quantum computers hold out the promise of performing certain calculations at speeds that would be impossible if the world ran by classical principles.

All of this has happened without any complete agreement on how quantum mechanics, at its core, actually works. Historically, advances in technology have often facilitated — or even necessitated — improvements in foundational understanding. We are continually inventing new ways to smack the television set called reality, remaining optimistic that a fuzzy picture will eventually snap into focus.

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Quantum theory has inspired many fascinating quotes from some of history's greatest minds.

"If quantum mechanics hasn't profoundly shocked you, you haven't understood it yet." — Niels Bohr

"I think I can safely say that nobody understands quantum mechanics." — Richard Feynman

"God does not play dice with the universe." — Albert Einstein

"Quantum mechanics is very imposing, but an inner voice tells me that it is not yet the real thing." — Albert Einstein

"There is no quantum world. There is only an abstract quantum mechanical description." — Niels Bohr

"The universe is not only queerer than we suppose, but queerer than we can suppose." — J.B.S. Haldane

"Reality is merely an illusion, albeit a very persistent one." — Albert Einstein

How do Black Holes evaporate?

Ethan Siegel

Astrophysicist, author, and
science communicator

Nothing in the Universe lives forever. All the stars that will ever form will someday burn out; distant galaxies and clusters of galaxies get pushed away from one another by dark energy; even the stars within a galaxy, on long enough timescales, will get gravitationally ejected. At the centers of galaxies, though, the largest single objects in the Universe form and grow even today: supermassive black holes. The most massive ones contain tens of billions of solar masses in a singularity surrounded by an event horizon, making them the most massive individual entities we know of. But even they won't live forever, and Jim Gerofsky wants to know what happens to cause them to die, asking: Just what is Hawking radiation? The science press articles keep referring to the electron-positron virtual pair production at the event horizon, which makes a lay person think that the Hawking radiation consists of electrons and positrons moving away from the black hole.

As discovered by Stephen Hawking in 1974, black holes eventually evaporate. This is the story of how.

The first thing you have to think about is what empty space truly is. Imagine emptiness as best you can; what would you remove?

You could take all the particles out of it, for starters. Any matter, antimatter, photons, radiation, or anything else you can imagine must all go. You need your space to be devoid of any quanta that could be present, or you won't be empty.

You'd also have to shield your empty region from the influence of anything outside of it. No electric, magnetic, or nuclear fields (or forces) should be allowed to penetrate it.

Even the gravitational influence of everything else in the Universe would have to be removed. That includes the curvature of space induced by any and all masses and all forms of energy, as well as any gravitational waves — or ripples in spacetime — that could pass through the space you occupy.

In our physical reality, we can't actually do this, but in theoretical physics, we can imagine it. Imagine a region of space with nothing in it or influencing it at all. The only things you won't be able to get rid of are spacetime itself, and the laws of physics that govern the Universe.

Yet even if we restrict ourselves to this type of emptiness, when we calculate what's going on in empty space itself, we find that it's not so empty. Instead, there's going to be a certain amount of energy inherent to the

fabric of space, owing to the fact that quantum physics is still real. Everything in the Universe has an inherent uncertainty in it: uncertain positions, uncertain momenta, and even and inherently uncertain amounts of energy to it.

Only by averaging everything out, over both time and space, can we obtain any meaningful information at all about what empty space is like.

The energy of empty space itself isn't something we can theoretically determine in an absolute sense; our calculational toolkit isn't powerful enough to do it. We can measure the energy inherent to empty space by mapping out the expansion of the Universe, though. The better we measure how the Universe is expanding, the better we constrain the properties of dark energy, which appears to equate to the energy of empty space. It's the best absolute measurement of the energy density of empty space we have.

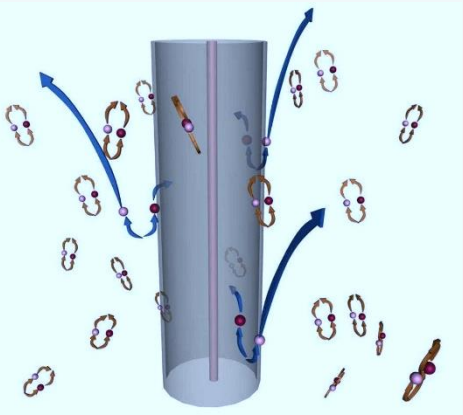
And, quite stunningly, that energy density, as much as we might recoil from the conclusion, isn't zero. The Universe's expansion is accelerating, and that implies that empty space itself has a positive, non-zero energy density.

So now, replace your empty spacetime with equally empty spacetime, with one exception: you plop down a single, point mass at a location of your choosing.

In technical terms, you're changing from Minkowski space to Schwarzschild space; in non-technical terms, you're adding a variable amount of spatial curvature to every location in your Universe. The closer you are to the mass, the more severely spacetime is curved, and there will even be a location where, no matter what type of particle you are or how fast you move or how much you accelerate, escape from within that region is impossible.

The border between being able to escape and not being able to is known as the event horizon, and ought to be a property of all black holes that exist in our Universe.

With all of this in mind, you might start to put some puzzle pieces together, just as Hawking did. Perhaps you're thinking, "okay, there are all sorts of particles and antiparticles that pop in-and-out of existence, filling empty space. And we now have an event horizon: a region from within which nothing can escape. So occasionally, perhaps, one of the particle pairs that pops into existence outside the event horizon crosses over to be inside the event horizon, before it can annihilate away. The other particle, therefore, can escape, and carry energy away from the black hole as it does."



Since energy has to be conserved, you might then put together one more puzzle piece, and claim that the energy must come from the mass of the black hole itself. This is very similar to the popular explanation Hawking put forth in explaining Hawking radiation, which details how black holes evaporate.

It's not right, though, in a number of ways. First off, this visualization is not for real particles, but virtual ones. We are trying to describe the quantum vacuum, but these are not actual particles that you can scoop up or collide with. The particle-antiparticle pairs from quantum field theory are calculational tools only, not physically observable entities. Second, the Hawking radiation that leaves a black hole is almost exclusively photons, not matter or antimatter particles. And third, most of the Hawking radiation doesn't come from the edge of the event horizon, but from a very large region surrounding the black hole.

If you must adhere to the particle-antiparticle pairs explanation, it's better to try and view it as a series of four types of pairs:

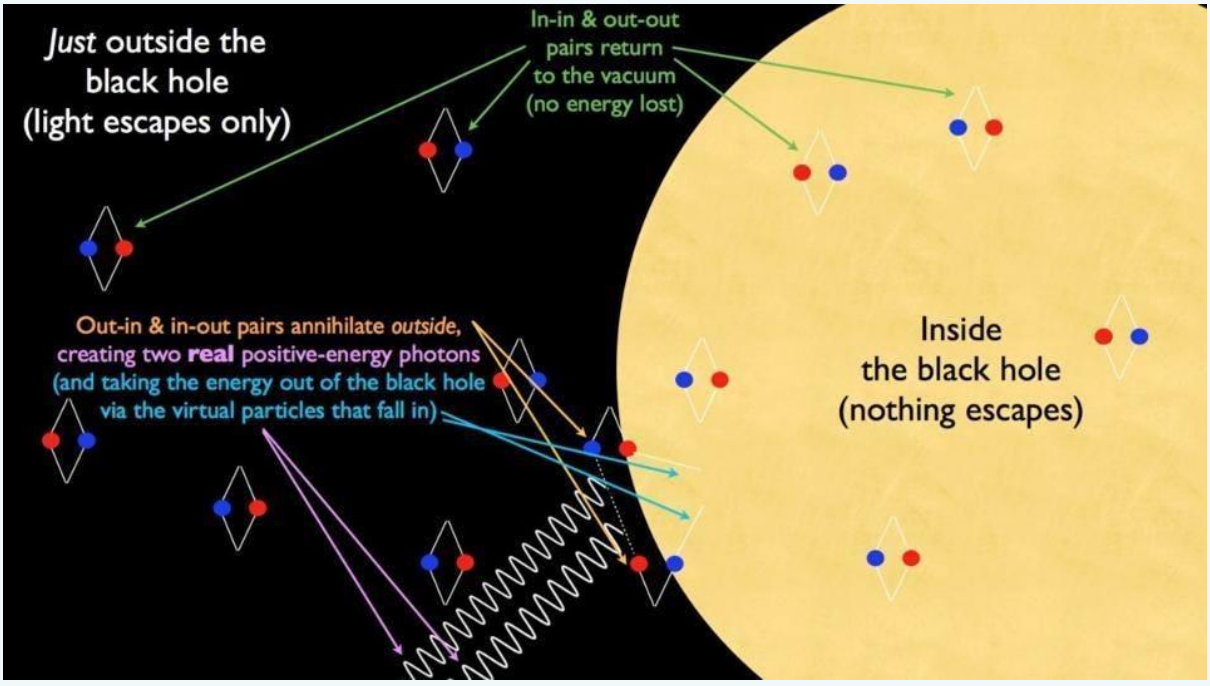
• out-out,

• out-in,

• in-out, and

• in-in,

where it's the out-in and in-out pairs that virtually interact, producing photons that carry energy away, where the missing energy comes from the curvature of space, and that in turn decreases the mass of the central black hole.



But the true explanation doesn't lend itself very well to a visualization, and that troubles a lot of people. What you must calculate is how the quantum field theory of empty space behaves in the highly-curved region around a black hole. Not necessarily right by the event horizon, but over a large, spherical region outside of it.

We cannot calculate the absolute energy of empty space, whether it's curved or uncurved, but what we can do is calculate the difference in the energy and properties of the quantum vacuum between empty and non-empty space.

When you perform the quantum field theory calculation in curved space, you arrive at a surprising solution: that thermal, blackbody radiation is emitted in the space surrounding a black hole's event horizon. And the smaller the event horizon is, the greater the curvature of space near the event horizon is, and thus the greater the rate of Hawking radiation.

The real explanation is a lot more complex, and shows that the simplistic picture of Hawking has its limits. The root of the problem isn't that particle-antiparticle pairs are popping in and out of existence, but that different observers have different views and perceptions of particles, and this problem is more complicated in curved space than in flat space.

Basically, one observer would see empty space, but an accelerated observer would see particles in that space. The origin of Hawking radiation has everything to do with where that observer is, and what they see as accelerated versus what they see as at rest.

The result is that black holes wind up emitting thermal, blackbody radiation (mostly in the form of photons) in all directions around it, over a volume of space that mostly encapsulates approximately ten Schwarzschild radii of the location of the black hole.

The big part of Hawking's explanation that's correct is that it does imply, given enough time, that black holes will not remain forever, but will decay away.

The loss of energy lowers the mass of the central black hole, eventually leading to evaporation. Hawking radiation is an incredibly slow process, where a black hole the mass of our Sun would take 1067 years to evaporate; the one at the Milky Way's center would require 1087 years, and the most massive ones in the Universe could take up to 10100 years! And whenever a black hole decays, the last thing you see is a brilliant, energetic flash of radiation and high-energy particles.

Yes, it's true that Hawking's original picture of particle-antiparticle pairs produced outside of the event horizon, with one escaping and carrying energy away while the other falls in and causes the black hole to lose mass, is oversimplified to the point of being totally wrong. Instead, radiation is formed outside the black hole owing to the fact that different observers cannot agree on what is happening in the strongly-curved space outside a black hole, and that someone who's stationary a far distance away will see a steady stream of thermal, blackbody, low-energy radiation emanating from it. The extreme curvature of space is the ultimate cause of this, and results in black holes, very slowly, evaporating away.

Those final decay steps, which won't occur until long after the final star has burned out, are fated to be the last gasps of energy the Universe has to give off. When the most massive black hole ever to exist finally decays away, it will be the last gasp for new quanta of energy that our Universe, as we know it, will ever create.

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Aliens – Myth or Reality?

Late C. R. Sathya

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Modern man developed certain inherent characteristics in the course of his evolution, important among them being, 'Curiosity'.

Figure-1: An alien: Speculative form (Alien PNGs by Vecteezy)

Curiosity was transformed into inquisitive nature. This is the beginning of science because this trait guided him to frame right questions in his attempt to understand nature around him. That he did not always get the right answer does not really matter. One such question which remained a mere question from ages is; do aliens exist? His desire to search for an answer to this question was further accentuated whenever he looked at the night sky and discovered the unfathomable size and depth of the star systems that made up the sky. He wondered; what lies beyond these stars; or, to be precise, in those stars or stellar systems? Is there life out there? Are there life forms like ours inhabiting them? If so, will they visit us or have they already visited us? What can be their forms or traits? Are they biological creatures like us or some other form of intelligent beings? If we come into contact with them, intentionally or accidentally, what will be the consequences; a friendly union of cultures or annihilation of our life forms?... and so on.

With the advancement of science and technology in recent times and with progress in knowledge in areas like astronomy, astrophysics and rocketry, we have conquered space; we have sent thousands of man-made satellites and scientific probes around the Earth and towards celestial bodies in our solar system. Some probes are heading even beyond the solar system. Man has landed on the Moon and will shortly travel to Mars. The scientific data collected in these endeavours are enormous with regard to the Earth and the solar system. Despite these achievements, there is no clue whatsoever as to whether we, the mankind, are alone in the universe or are there others who inhabit star systems beyond our reach as of today. Absence of solutions to these puzzles have also raised many doubts which, some people say, are scientific and some people dub as fictitious. However, both are capable of arousing exceptional curiosity in us. One can reject such theories, but it is not easy for anyone to ignore.

Some believe that aliens do exist. They are conceived as weird looking creatures, with some resemblance to human form. Science fiction, popularly known as 'Sci-fi' novels by leading authors, has turned millions of readers into believers in the existence of alien. But let me iterate; *belief does not make up science*. So also, innumerable Hollywood films have captured the imagination of viewers by casting aliens as villains in the stories. *Films do not teach science*.

And then we have heard stories doing rounds; Unidentified Flying Objects - the UFOs - are claimed to have been seen by hundreds of people, some reports authenticated with photographs of dazzling and dish shaped objects moving at enormous speeds across the sky and disappearing without trace as suddenly as they appear. Most of those reports are brushed aside as streaks of imagination aided by morphed photos or videos. Strange thing is, while there are official denials by many governments and scientific bodies about the existence of aliens or UFOs, there are hundreds of members among the general public, scientists, pilots and astronauts who claim to have noticed inexplicable bodies in the sky.

Supporters of alien theory also speculate that their intelligence level is far higher than ours as otherwise they would not be able to travel vast distances across star systems to come anywhere near us. Perhaps they are just robotic messengers sent out to survey the universe by some superior race that exists elsewhere or existed millions of years ago. They must have been backed by the state-of-the-art technology with ability to travel interstellar distances with renewable energy sources, to live out vast time frames - unimaginable by organic beings like us limited by narrow lifespan compared to theirs - and who may possess communication systems that link distant stars; or may be galaxies too. Some inexplicable geometrical patterns are alleged to have been seen in some countries at several locations like ground and mountain tops and objects with strange shapes on the surface of the moon or Mars (inferred by images beamed from there), which look like life forms or man-made objects, are projected as evidence. Speculation is that no governments may announce the existence of aliens among us as it would create panic among the general public who may fear that they may take over our supremacy.

Figure-2: Typical UFO

Image by Peter Lomas from Pixabay

The turning point to the speculation came with the initiative taken in 1961 by Frank Drake, then a young American astronomer, who postulated that if at all aliens are there, they must be intelligent enough to have developed a communication technology to reach out to other civilizations and if so, they should be beaming radio signals of a specific format for us to recognize and respond. He felt that if we set up an array of radio receivers big enough to sweep the sky and are able to catch even the weakest signals, then we can possibly find some evidence for the existence of an alien. His view was endorsed by other fellow-astronomers including the famous Carl Sagan. The resulting outcome is what is now known as Drake's equation which, by a process of logical explanations and

elimination, suggests that a finite number of civilisations may exist elsewhere in this vast universe. The equation reads like this: $N=R_*f_pn_ef_if_if_cL$

where

N=the number of civilizations in this galaxy, called 'Milky Way', whose electromagnetic emissions are detectable,

R_* = is the rate of formation of stars suitable for the evolution of intelligent life,

f_p= is the fraction of those stars with planetary systems,

n_e= is the number of planets, per solar system, suitable for life,

f_l= is the fraction of suitable planets on which life actually appears,

f_i = is the fraction of life bearing planets on which intelligence emerges,

f_c = is the fraction of civilizations which develop a technology that releases detectable signals of their existence to space and

L = is the length of time that civilisations release detectable signals into space.

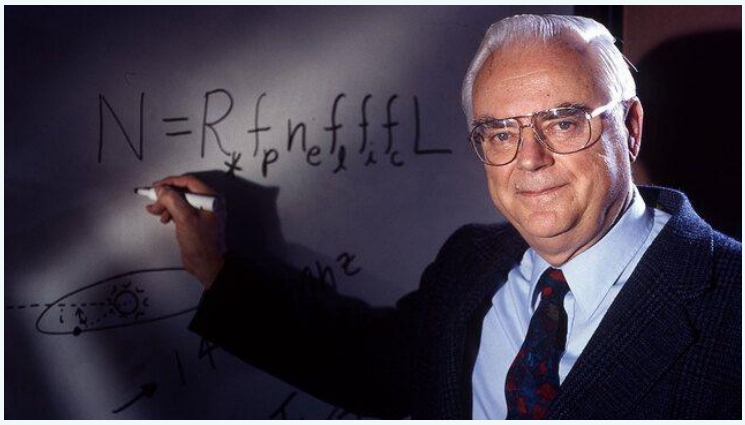


Figure-3: Frank Drake with his famous equation
Photo Attribute: https://www.seti.org/

Besides illuminating the factors involved in such a search, the Drake equation also became a simple, but effective tool to simulate intellectual curiosity about the universe around us and to help us understand the evolution of life. The last one is very important because it is an indispensable part of the evolution of the universe. Such an understanding makes us realise that humans are parts of evolution of the universe too which is truly one of the greatest enigmas of our times. This formulation also led to the evolution of radio astronomy and astrobiology. More importantly, a project called SETI (Search for Extra-terrestrial Intelligence) got priority status. As a result, a large number of scientists set up their systems and giant radio telescopes to look at the sky in search of intelligible signals. However, so far, no decipherable signals have been received to confirm this hypothesis. The first of the 'Exo-planets' which were spotted, however, revealed a surface temperature of nearly 1000° C and these planets were found to circle their parent star once in four Earth days. But the conditions prevailing on this planet were not found suitable for the origin and sustenance of at least known types of life forms, forget beings more advanced than humans. The hunt, however, was continued for the habitable planets and two such were soon discovered in the following year. But a turning point came in March 2009 when the USA launched the space telescope 'Keppler' which, in spite of several glitches in its operations, revolutionised the mapping of the universe and of exo-planets in particular. About one fifth of planets, which Keppler spotted, are assumed to have conditions that might harbour life and one of them is found to be just 12 light years away.

Figure-4: Radio receiver array under SETI Project
Image : https://www.seti.org

A key point to Drake's equation is the possibility of the evolution of life on such planets due to conditions supposed to be favourable to the origin of life, at least in the most primitive form. It is important to note that if this is ruled out, then we cannot even imagine the existence of more advanced beings. Initially, life evolved on the Earth with the formation of living cells by chemical processes involving primary ingredients like water, carbon dioxide, nitrogen and sulphur. However, it is yet to be conclusively proved whether these ingredients of life were part of the Earth from its formative time or were deposited here by asteroids or comets.

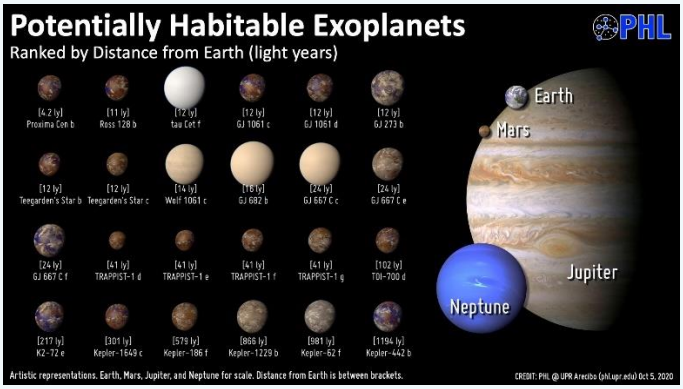
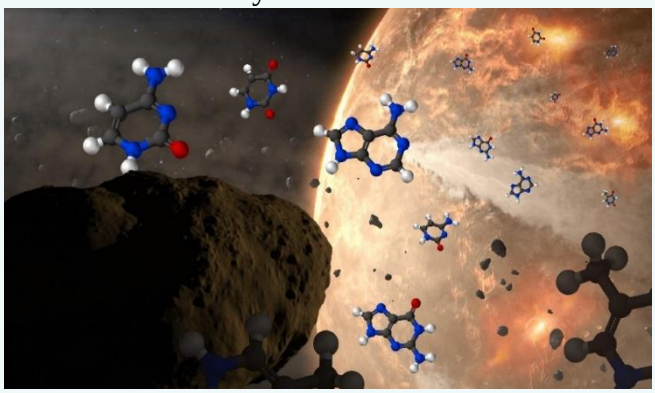


Figure-5 : Search for exo-planets

The current list of potentially habitable exoplanets (as of October 5, 2020), ranked by distance from Earth (in light years). Credit: Planetary Habitability Laboratory, University of Puerto Rico at Arecib

Scientists started working on the suggestion that life evolving ingredients might have originated on asteroids or comets. At some point of time, they came up with a basic question; whether the atmosphere and extreme conditions of the environment in such extra-terrestrial bodies can harbour any type of life. Astrobiologists soon realised that different forms of life can not only evolve in extreme conditions far different from what we experience but also thrive well and such examples have been found right on the Earth. Bacteria have been found to thrive at very high temperatures, perhaps with dissolved hydrogen sulphide and other chemicals as their food sources, in the eruptions of hot steam or gasses from some fissures on the Earth's surface or in volcanic caves. Microbes are found living under the Antarctic ice - the other extreme -and also in acidic, oxidising and highly saline environments including some places where they are subjected to many hazardous radiations. So, the speculation is that if life forms can adapt to such a hostile - relative to ours - environment on the Earth, then there is every possibility that elsewhere in the universe life forms can be thriving in an environment which can be far different from ours. So, speculation acquires all the

characteristics of a theory. However, their physiology or pattern of living or intelligence is not in the grasp of the scientists as yet.



This conceptual image shows meteoroids delivering nucleobases to ancient Earth. The nucleobases are represented by structural diagrams with hydrogen atoms as white spheres, carbon as black, nitrogen as blue, and oxygen as red.

NASA Goddard / CI Lab / Dan Gallagher

Figure-6: Organic cells from extra-terrestrial bodies to the Earth

Space scientists gathered data from spacecraft and land-based observations which led them to conclude that water - so essential for life - is available on Mars in liquid form and it is below the Martian soil. Same is the inference with respect to Europa, a satellite of Jupiter, and also the moon. It is believed that water flowed on the surface of Mars also long ago, but evaporated due to its low gravitational pull. Does that mean that some form of life existed on the surface of Mars a long time ago or are they still present in sub-Martian tables? Many are scrutinising pictures beamed by the Mars Rover (the robotic vehicle now exploring the surface of Mars) and are hunting out for shapes, forms or objects that resemble artifacts of a civilised community. Recently, the European Space Agency sent out a spacecraft called Rosetta which made a rendezvous with a passing asteroid called '67 P Churyumor-gerasimenko' and landed a robotic sniffer named Philae on to the surface of the asteroid to sniff its atmosphere and detect signs of life on its surface or in its environment. Short lived, though for technical reasons, the data sent are still under analysis now.

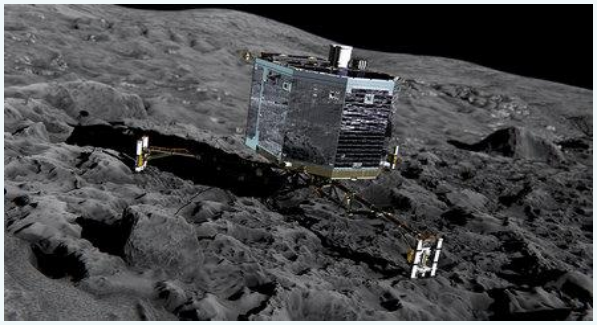


Figure-7: Philae on asteroid soil
Image attributed to: https://www.esa.int/

Image: www.independent.uk
https://www.independent.co.uk/arts-entertainment/films/news/a-cut-above-the-rest-steven-spielberg-to-release-original-edit-of-e-t-7817888.html

Thus, the hunt is still on without any tangible evidence of life out there. And now, Frank Drake is postulating an alternative to radio-based search. He believes that we can expect high powered light beams, like that of laser, from some exo-planets which are easily discernible and can travel across the width and depth of space. Whatever it may be, the existence of aliens is still a big question to be answered and until then we need to live with animated creatures in sci-fi films and computer games. But then, one cannot be sure, if they are already there and are amidst us. Do not be scared if there is a tap on your door in the middle of the night and as you open the door, a strange creature in a computer synthesised voice asks you; 'May I come in?'

Dark matter might lurk in its own shadow world

Dr. Kathryn Zurek

Theoretical physicist, California Institute of Technology, USA

Have you ever stood by the sea and been overwhelmed by its vastness, by how quickly it could roll in and swallow you? Evidence suggests that we are suspended in a cosmic sea of dark matter, a mysterious substance that shapes galaxies and large structures in the universe but is transparent to photons, the carriers of the electromagnetic force. Our galactic home, the Milky Way, is submerged in dark matter, but this hidden body but does not devour us, because its forces cannot touch the regular matter we're made of.

Everything we know about dark matter comes from measuring its gravitational pull, but gravity is the weakest of nature's forces—so feeble that the electromagnetic forces that bind atoms to make a chair we can sit in are enough to counteract the gravitational force of the entire Earth. Just as we need the electromagnetic force to tell us about protons, neutrons, electrons and the richness of all the particles we know of—collectively called the Standard Model of particle physics—we need more than gravity to unlock the secrets of the dark side. As a result, the past three decades of the search for dark matter have been characterized by null results. For most of that time, researchers have been looking for a single particle to explain dark matter.

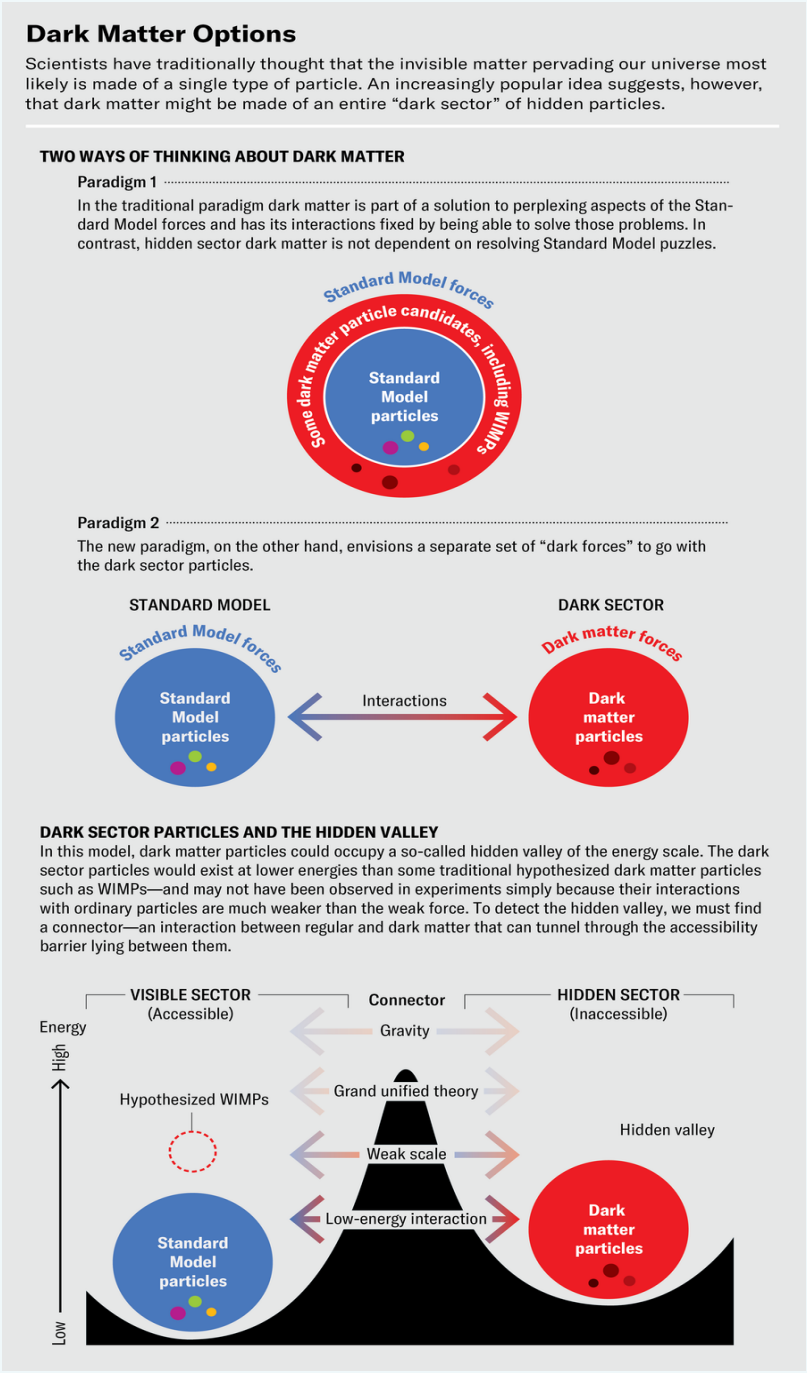
Yet dark matter might not be one particular particle—it may be a whole hidden sector of dark particles and forces. In this dark sector, particles would interact through their own independent forces and dynamics, creating a hidden world of cosmology running parallel to our own. There could be dark atoms—made of dark protons, dark neutrons and dark electrons—held together by a dark version of electromagnetism. The carriers of this force, the dark photons, might (unlike our photons) have mass, allowing huge dark atomic nuclei—so-called nuggets—to form. And the totally different dynamics of dark matter in this dark sector would have different effects on the evolution of normal matter throughout time. The interactions of nuggets in galaxies could help form supermassive black holes in the centers of galaxies, causing them to grow larger than they otherwise would.

Dark matter might not be one particular particle—it may be a whole hidden sector of dark particles and forces.

As other, simpler theories of dark matter have failed to find experimental confirmation, the dark sector concept has gained traction. My colleagues and I have also developed novel plans for experiments that can search for this type of dark matter. These experiments use techniques from condensed matter physics to attempt to uncover a sector of the cosmos we've never searched for before.

When I entered the dark matter hunt in 2005, physicists were focused on searching for dark matter whispers from the weak force. Despite its name, the weak force is much stronger than gravity, and scientists suspected that dark matter might communicate with our world through this force. They built many extremely sensitive experiments, buried underground where everything is quiet, to attempt to hear such murmurs.

It was an exciting time because astrophysicists were also seeing unexplained data coming from the center of the Milky Way that might have been a sign of dark matter producing a haze of photons from some kind of interaction with the weak force. I found these ideas intriguing, but I wasn't convinced that the Milky Way signal came from dark matter. It seemed premature to focus the search for dark matter on theories related to the weak force. In addition, many processes from ordinary physics produce the microwave photons that were emanating from the center of our galaxy.



At the first dark matter conference I attended after graduate school, I took a bet with a primary proponent of the "dark matter haze" idea, Dan Hooper of the University of Wisconsin–Madison. Hooper thought we could confirm that these observations were caused by dark matter within the next five years. I took the sceptical position. The stakes of the bet: whoever lost would have to say that the other was right in each of their scientific talks for one year. It was a consolation that if I lost, I could still bask in the joy of dark matter having been discovered. This bet would accompany me for the next 13 years of my scientific career.

Sometimes our assumptions end up binding us, preventing us from finding the solutions we seek. The first ideas for the nature of dark matter focused on solving the theoretical problems of the Standard Model, which describes not just the known particles but the quantum forces (electromagnetism, the weak force and the strong force). Two puzzles of the model are why the weak force is so much stronger than gravity (what physicists call the hierarchy problem) and why the strong force—the force that binds atomic nuclei—doesn't notice the difference between

mirrored particles and antiparticles (called the strong charge conjugation–parity, or strong CP, problem). Particle physicists hypothesized that adding new particles to the Standard Model could help us understand why the known particles behave like they do. These new particles might also exist in the right quantities to explain dark matter.

Two categories of particles emerged as popular candidates. One group, called WIMPs (for weakly interacting massive particles, lest you doubt the field has humor), features in solutions to the hierarchy problem. Another set of proposed particles, axions (after the laundry detergent, as a metaphor for cleaning up the problem), offered a solution to the strong CP problem.

I thought, however, that we should question the premise that dark matter also solved the Standard Model problems. My imagined particles didn't interact via any Standard Model forces—they would have their own independent forces and dynamics—so they couldn't solve that model's mysteries. They were also much lower in mass than WIMPs and occupied a hidden valley of the energy and mass scale for particles. This idea, which I proposed around 2006, went counter to the trend in high-energy physics, which focused on building huge experiments, such as CERN's Large Hadron Collider near Geneva, to produce the increasingly massive particles that theorists envisioned. In contrast, hidden valley particles would occupy much lower-energy territory and may not have been observed in experiments simply because their interactions with ordinary particles are much weaker than the weak force.

Without the idea that dark matter should solve either the hierarchy problem or the strong CP problem, an entire range of new models became theoretically viable and consistent with observations of our universe. I focused on the idea that the hidden valley provided a natural host for the dark matter sector. The different dynamics of dark matter in the dark sector compared with WIMPs would have different effects on the evolution of normal matter throughout time.

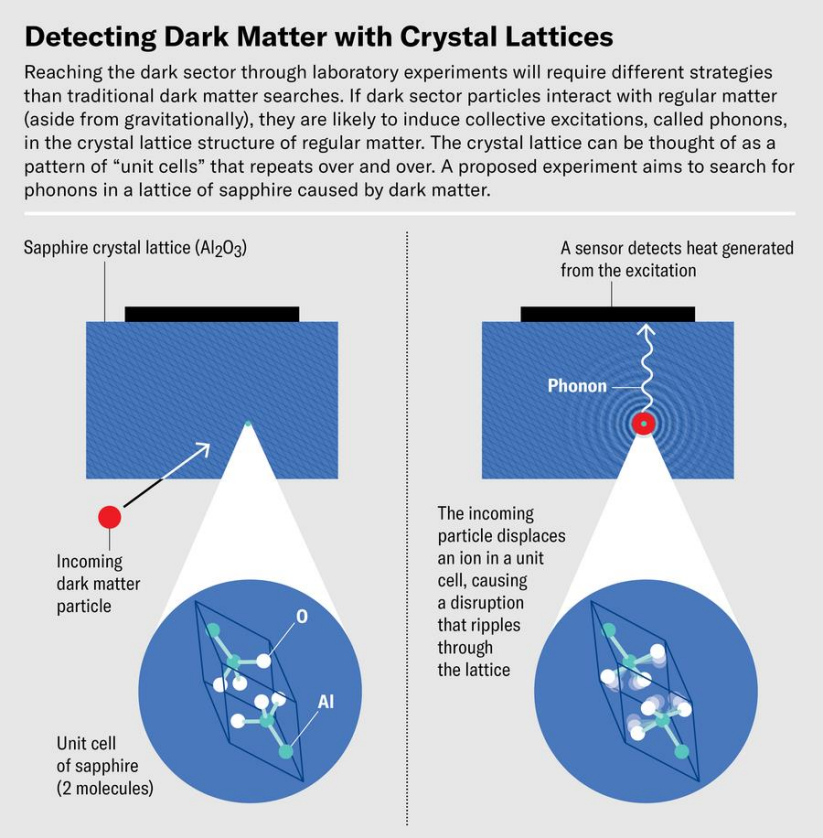
As my colleagues and I studied the possible implications of a dark sector over the next decades, the range of observable consequences in our universe blossomed. The field looks completely different now. Dark sector theories have been aided along the way by fortuitous experimental anomalies.

The lucky anomalies arrived in 2008 from experiments that had been looking for WIMP dark matter. By this time experimentalists had already spent two decades building Earth-based experiments to look for dark matter from the supposed sea that must be passing through Earth at all times. In 2008 three of these saw a mysterious, unexplained rise in "events" at low energies. An event, in this case, means that a single dark matter particle may have slammed into a regular atomic nucleus in the detector and given it a kick of energy. The experiments registered events that could have been caused by dark matter particles weighing a few times the mass of the neutron.

The excesses in these experiments electrified me because they were consistent with a theory of hidden valley dark matter I had proposed the previous year. I called this theory asymmetric dark matter. The theory was based on the idea that the amount of dark matter in the universe is determined by how that matter interacts with neutrons and electrons. We can take this number, set by theory, and combine it with the total mass of all the dark matter in space (which we know from astronomical observations) to calculate the mass of the most

common dark sector particles. It turns out that the theorized particles should weigh about as much as neutrons—just what the experiments were observing.

The arrival of these anomalies made the field of hidden sector dark matter very popular. The online repository for new physics papers exploded with studies suggesting possible explanations for the excesses with different types of hidden sectors. It suddenly seemed I might lose my bet that dark matter would keep itself hidden. But the observations and the theories weren't quite lining up, and the models became more baroque and contorted to fit the experimental data. By 2011 my belief that the anomalies could be evidence of dark matter faded.



Not everyone agreed. Hooper, ever the optimist, still thought that the anomalies could be dark matter, so he upped the bet and threw in two top-shelf bottles of wine. Eventually, though, further checks of the anomalies convinced most physicists that most of the observations must have a mundane explanation, such as a background signal or detector effects contaminating the data. My top-shelf bottles of wine from Hooper arrived during the pandemic in 2020.

But that wasn't the end of the story. The long-term impact of these anomalies opened researchers' minds to new theories of dark matter beyond WIMPs and axions. This change was aided by the fact that decades' worth of experiments designed to find WIMPs and axions had so far turned up nothing. Even the Large Hadron Collider, which many scientists expected to find WIMPs and other new particles, found nothing new except for the last unconfirmed piece of the Standard Model, the Higgs boson. More and more physicists recognized that we needed to widen our search.

In 2014 I moved from the University of Michigan to Lawrence Berkeley National Laboratory, where I turned my attention from dark matter theories to devising new methods of dark matter detection. Working in this area radically broadened my horizons in physics. I learned that studying the fundamental forces of nature is not sufficient to understand how dark matter might interact with regular matter. For such rare and weak communications between particles, the interactions between the fundamental constituents of matter (the nucleons and electrons in atoms) become paramount. In other words, to understand how a dark matter particle might affect a typical atom, we must consider the small interactions among the atoms arranged in a crystal lattice inside a material. Imagine the coils in an old-fashioned mattress: if one part of a coil gets pushed down, it propagates waves through the entire mattress.

Because many materials work like this, it stood to reason that if dark matter were to disturb one atom in a lattice of "normal" matter, it would set up a propagating disturbance. These collective disturbances, which involve many atoms, are quantum in nature and are called phonons or magnons. Understanding phonons is the domain of condensed matter and solid state physics, which focus on the collective effects of many atoms within a material. Because materials can be made up of lots of different kinds of atoms and molecules, with different bonds between them, the collective disturbances take on many forms, becoming a zoo of possible interactions.

What we have achieved in the past 20 years is a dramatic opening of the theoretical possibilities for dark matter and the ways to find it.

One of my challenges was to understand how dark matter might interact with these collective phenomena. To do that, I needed a useful model that described all the complicated effects with just a few parameters. I found that I could predict how likely different kinds of dark matter were to interact with a material if the force governing the interaction was the same as the force responsible for dark matter's abundance in our universe.

I ran into some practical challenges. Not all physicists speak the same physics language. In addition, each field tends to focus on just a few questions when studying a physical system. I was interested in very different questions than those that interest most practicing condensed matter physicists. And as a dark matter physicist collaborating with condensed matter physicists on collective excitations for the first time, I had barriers to surmount. Once I discovered how to rephrase my understanding of the dark matter interaction problem in the jargon used by condensed matter and atomic physicists, my students, postdocs and I were able to progress much more quickly.

In time, a new world of collective phenomena opened before us. We discovered that condensed matter and atomic, molecular and optical physicists had fun applying their portfolio of materials and detection mechanisms to the hunt for dark matter. After a few years of playing with an abundant array of ideas, we realized we needed to focus on just a few for experimental development. We ended up picking two materials that seemed like promising targets, both for their fundamental dark matter interactions and for how feasible their use in experiments was. Now we are actively designing experiments using these materials that we hope to run in the coming years.

The first category is polar materials, such as quartz and sapphire, which produce strong phonons with a collective energy that is a good match for dark matter and which seem like they would communicate well with a dark photon. The second material is superfluid helium, which is free from many of the defects that plague solid materials with crystal lattices. This liquid features light nuclei that may have a relatively good chance of interacting with dark matter.

For the next steps, our experimental partners are leading the way. My former Lawrence Berkeley Lab colleagues have developed two of the most promising ideas. Matt C. Pyle has proposed an experiment called SPICE (Sub-eV Polar Interactions Cryogenic Experiment), which would use a polar material such as sapphire for a detector. Another experimentalist, Daniel N. McKinsey, has envisioned the HeRaLD (Helium and Roton Liquid Detector) project, which would use superfluid helium.

Our theoretical work suggests that small samples of the target materials—one kilogram or less—could be enough to begin testing our theories. Although these samples would not require much material, they would have to be free of defects and be placed in very quiet and contaminant-free environments. Fortunately, through earlier generations of dark matter experiments searching for WIMPs, Pyle and McKinsey already have experience in reducing sources of noise and radioactivity by working deep underground.

Although all the theoretical ideas are in place for these experiments, it will take a long time to put them into action. Both projects have received a round of funding from the Department of Energy's Office of Science to further develop the concepts. Over the past four to five years, however, we've discovered new background processes that might imitate the signals we're hunting for, which we'll have to find ways to block. Because of these large backgrounds, the detectors are not nearly sensitive enough yet to discover dark matter. It may take a decade or more, as it did for the earlier generations of WIMP experiments, to learn how to make these detectors so quiet that they can listen for dark matter whispers.

Still, what we have achieved in the past 20 years is a dramatic opening of the theoretical possibilities for dark matter and the ways to find it. The fundamental nature of the dark matter that pervades our universe is still unresolved. As I work on this problem, I like to think about the building of cathedrals in centuries past, which were constructed over generations, each stone carefully placed on the last. Eventually, by building our understanding of dark matter bit by bit, we hope to reach a true comprehension of all of nature's constituents.

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Dark Matter: The Invisible Architect of the Cosmos

1. **Dominant Component of the Universe's Mass** Dark matter constitutes approximately 27% of the universe's total mass-energy content, significantly outweighing the ordinary matter that makes up stars, planets, and galaxies.

2. **Gravitational Influence on Cosmic Structures** It serves as the gravitational scaffolding for galaxies and galaxy clusters, influencing their formation and organization on a grand scale.

3. **Facilitating Galaxy Formation** Dark matter's gravitational pull helps gather gas and dust, enabling the formation of stars and galaxies. Its presence is crucial for the development of large-scale cosmic structures.

4. **Detectable Through Gravitational Effects** Although invisible, dark matter's presence is inferred through its gravitational effects, such as bending light from distant galaxies, a phenomenon known as gravitational lensing.

5. **Influence on the Universe's Evolution** Dark matter plays a pivotal role in the universe's expansion and evolution, affecting the formation of the cosmic web and the distribution of galaxies.

6. **Ongoing Research and Exploration** Scientists continue to study dark matter to understand its properties and interactions, aiming to uncover the mysteries of the universe's unseen.

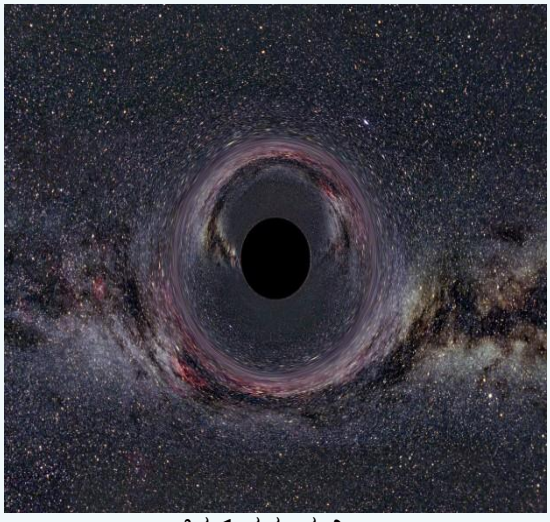
Source: Internet

ಕಪ್ಪು ಕುಳಿಗಳು (*BLACK HOLE*)

ಡಾ. ಶಾರದಾ ನಾಗಭೂಷಣ

ಕಪ್ಪು ಕುಳಿ ಅಥವಾ ಕಪ್ಪು ರಂಧ್ರಗಳು ವಿಶ್ವದ ಅತಿ ನಿಗೂಢವಾದ ಆಕಾಶ ಕಾಯಗಳು. ಅವು ಅತಿ ಹೆಚ್ಚಿನ ಸಾಂದ್ರತೆ ಮತ್ತು ಗುರುತ್ವವನ್ನು ಹೊಂದಿದ್ದು ತನ್ನಿಂದ ಬೆಳಕೂ ಸೇರಿದಂತೆ ಯಾವುದನ್ನೂ ಹೊರಹೋಗಲು ಬಿಡುವುದಿಲ್ಲ.

ಕನಿಷ್ಠ 3–4ರಷ್ಟು ಸೌರದ್ರವ್ಯರಾಶಿಯುಳ್ಳ ನಕ್ಷತ್ರವು ತನ್ನ ಅಂತಿಮ ಘಟ್ಟದಲ್ಲಿ ತನ್ನಲ್ಲಿರುವ ಇಂಧನವಾದ ಜಲಜನಕವನ್ನು ಉರಿಸಿ ಖಾಲಿಮಾಡಿ, ಅತಿಯಾದ ಸಾಂದ್ರತೆಯಿಂದ ಕೂಡಿದ್ದು ಹೆಚ್ಚು ಗುರುತ್ವವನ್ನು ಹೊಂದಿರುತ್ತದೆ. ಅಂತ್ಯದಲ್ಲಿ ಅತೀವ ಪ್ರಕಾಶದಿಂದ ಸೂಪರ್ನೋವಾ ಆಗಿ ಸ್ಫೋಟಗೊಂಡು, ಕೆಲವು ಭಾಗಗಳು ಅಂತರ ತಾರಾ ವಲಯದಲ್ಲಿ ಚದುರಿಹೋಗಿ, ಮಧ್ಯದ ಭಾಗವು ಗುರುತ್ವದಿಂದ ಕುಸಿದು ಕಪ್ಪು ಕುಳಿಯಾಗಿ ಮಾರ್ಪಾಡಾಗುತ್ತದೆ. ಈ ಕಪ್ಪು ಕುಳಿಯಿಂದ ಬೆಳಕೂ ಸೇರಿದಂತೆ ಯಾವುದೂ ಹೊರಗೆ ತಪ್ಪಿಸಿಕೊಂಡು ಹೋಗುವುದು ಸಾಧ್ಯವಿಲ್ಲ. ಇದು ಅತಿಯಾಗಿ ಸಾಂದ್ರೀಕೃತವಾದ ದ್ರವ್ಯರಾಶಿಯಿಂದ ಉಂಟಾದ ನಾಲ್ಕು ಆಯಾಮದ ಸ್ಪೇಸ್–ಟೈಮ್‌ನ ಕಾಯವಾಗಿದೆ (ಚಿತ್ರ 1). ಈ ಕಪ್ಪು ಕುಳಿಯ ಸುತ್ತ ಒಂದು ಕಾಲ್ಪನಿಕ ಹೊರಮೈ ಇದ್ದು, ಇದು ಯಾವ ವಸ್ತು ಮತ್ತು ಬೆಳಕನ್ನೂ ಹಿಂದಿರುಗಿಸಲಾಗದ ಆಯಾಮವನ್ನು ಸಂಕೇತಿಸುತ್ತದೆ. ಇದನ್ನು 'ಈವೆಂಟ್ ಹೊರೈಜನ್' (*Event Horizon*)ಎಂದು ಕರೆಯಲಾಗುತ್ತದೆ.



ಚಿತ್ರ 1 ಕಪ್ಪು ಕುಳಿ

ಕಪ್ಪು ಕುಳಿಯೇರ್ಪಡುವ ಬಗೆ: ನಮ್ಮ ಸೂರ್ಯನಂತಹ ಕುಬ್ಜ ನಕ್ಷತ್ರಗಳು ತಮ್ಮಲ್ಲಿರುವ ಇಂಧನವನ್ನು ಉರಿಸುತ್ತಾ 8–10 ಶತಕೋಟಿ ವರ್ಷಗಳತನಕ ಪ್ರಕಾಶಿಸುತ್ತಿದ್ದು ಅದು ಮುಗಿದನಂತರ ಅಂತಿಮ ಘಟ್ಟದಲ್ಲಿ ಗುರುತ್ವದಿಂದ ಕುಸಿದು ಶ್ವೇತಕುಬ್ಜ (*white dwarf*)ಗಳಾಗುತ್ತವೆ. ಸುಮಾರು 3ರಷ್ಟು ಸೌರ ದ್ರವ್ಯರಾಶಿಯುಳ್ಳ ದೈತ್ಯನಕ್ಷತ್ರಗಳು ತಮ್ಮ ಅಂತಿಮ ಘಟ್ಟದಲ್ಲಿ ತಮ್ಮ ಎಲಕ್ಟ್ರಾನ್ ಅವನತಿ ಒತ್ತಡವು (*Electron degeneracy pressure*) ಗುರುತ್ವ ಶಕ್ತಿಯನ್ನು ಎದುರಿಸಲಾರದೆ, ನಕ್ಷತ್ರದ ಒಳಗಿನ ದ್ರವ್ಯಗಳು ಕುಸಿದು ಸುಮಾರು 20 ಕಿ.ಮೀ. ವ್ಯಾಸದ ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರ(*Neutron Star*)ಗಳಾಗುತ್ತವೆ.

ಬೃಹತ್ ದೈತ್ಯ ನಕ್ಷತ್ರಗಳಾದ ಕನಿಷ್ಠ 3.8 ಸೌರ ದ್ರವ್ಯರಾಶಿ ಅಥವಾ ಅದಕ್ಕಿಂತ ಹೆಚ್ಚಿನವು, ತಮ್ಮ ಪ್ರಕಾಶಿಸುವ ಇಂಧನವು ಮುಗಿದ ನಂತರ, ಅಂತಿಮಘಟ್ಟದಲ್ಲಿ ಎಲಕ್ಟ್ರಾನ್‌ಗಳ ಶಕ್ತಿಯು ಅತಿಯಾದ ಗುರುತ್ವ ಶಕ್ತಿಯನ್ನು ಎದುರಿಸಲಾರದೆ ಸೂಪರ್ನೋವಾ ಆಗಿ ಸಿಡಿದು, ಉಳಿದ ಕೇಂದ್ರ ಭಾಗವು ತಮ್ಮೊಳಗೇ ಬೆರೆತು ವಿಲೀನಗೊಂಡು ಏಕತ್ವವನ್ನು(*Singularity*) ತಲುಪಿ **'ಕಪ್ಪು ಕುಳಿ'** (*Black Hole*)ಯಾಗಿ ಮಾರ್ಪಡುತ್ತವೆ. ಇದರ ಸುತ್ತಲೂ ನಿರ್ವಾತ ಪ್ರದೇಶವೇರ್ಪಟ್ಟು ಕಾಣಲಾಗದ ತುದಿಯನ್ನು ತಲುಪುತ್ತದೆ. ಇದನ್ನು 'ಈವೆಂಟ್ ಹೊರೈಸನ್' (*Event Horizon*) ಎನ್ನುತ್ತಾರೆ. ಇದು ಹಿಂದಕ್ಕೆ ಬರಲಾಗದ ಕಾಲ್ಪನಿಕ ಎಲ್ಲೆಯಾಗಿದ್ದು ಅದರಿಂದ ಒಳಗೆ ಯಾವುದೇ ಘಟನೆಗಳು ಜರುಗಿದರೆ ಉಳಿದ ಆಕಾಶಕಾಯದ ಮೇಲೆ ಯಾವ ಪರಿಣಾಮವನ್ನೂ ಬೀರುವುದಿಲ್ಲ. ಇದರ ಒಳಗೆ ಅಗಾಧವಾದ ಗುರುತ್ವಶಕ್ತಿಯಿದ್ದು ಯಾವ ದ್ರವ್ಯವೂ ಮತ್ತು ಬೆಳಕೂ ಕೂಡ ಇದರೊಳಗಿಂದ ತಪ್ಪಿಸಿಕೊಂಡು ಹೊರಗೆ ಹೋಗಲು ಸಾಧ್ಯವಿಲ್ಲ. ಅಂತೆಯೇ ಯಾವ ಖಗೋಳ ಕಾಯವೇ ಆಗಲಿ ಈವೆಂಟ್ ಹೊರೈಸನ್ ಸಮೀಪ ಬಂದಲ್ಲಿ ಅದನ್ನು ತನ್ನೊಳಗೆ ಎಳೆದುಕೊಳ್ಳುತ್ತದೆ. ಹೊರಭಾಗದಿಂದ ಈ ಕಾಲ್ಪನಿಕ ಎಲ್ಲೆಯು 'ಸ್ಪೇಸ್–ಟೈಮ್'ನಿಂದ ಸುತ್ತಿಕೊಂಡು ಬಾಗಿರುತ್ತದೆ.

ಯಾರಾದರೂ ಈ ಎಲ್ಲೆಯಲ್ಲಿ ಸುಳಿದಾಡಿದರೆ (ಅಲ್ಲಿಗೆ ಹೋಗಲು ಸಾಧ್ಯವೇ ಇಲ್ಲ) ಐನ್ಸ್‌ಟಿನ್ನರ ಸಿದ್ಧಾಂತವಾದ 'ಸಮಯದ ಹಿಗ್ಗುವಿಕೆ'ಯ ($Time\ dilation$) ಪ್ರಕಾರ ಅವರು ಭೂಮಿಯ ಮೇಲಿನದಕ್ಕಿಂತ ನಿಧಾನವಾಗಿ ಪ್ರಯಾಣಿಸುವ ಸಮಯವನ್ನು ಅನುಭವಿಸುತ್ತಾರೆ.

ಭೂಮಿಗೆ ಅತಿ ಸಮೀಪದಲ್ಲಿರುವ ಕಪ್ಪು ಕುಳಿಯೆಂದರೆ 1500 ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿರುವ 'ಗಿಯ' ($Gaia$) ಎಂಬ ಕಪ್ಪು ಕುಳಿ. ಅತಿ ದೂರದ ಕಪ್ಪು ಕುಳಿಯು 13 ಶತಕೋಟಿ ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದ $QSOJ0313-1806$ ಎಂಬ ಗ್ಯಾಲಾಕ್ಸಿಯ ಮಧ್ಯದಲ್ಲಿ ಇದೆ. ಅತಿ ದೊಡ್ಡ ಕಪ್ಪು ಕುಳಿಯಾದ $TON618$ ಎಂಬುದು 66 ಶತಕೋಟಿ ಸೌರ ದ್ರವ್ಯರಾಶಿಯಷ್ಟು ಇದೆ. ಅತಿ ಹಗುರವಾದ ಕಪ್ಪು ಕುಳಿಯು 3.8 ಸೌರ ದ್ರವ್ಯರಾಶಿಯಷ್ಟು ಇದ್ದು ಒಂದು ನಕ್ಷತ್ರದೊಡನೆ ಯುಗಳ ವ್ಯವಸ್ಥೆಯಲ್ಲಿದೆ. (ಜ್ಯೋತಿರ್ವರ್ಷವೆಂದರೆ ಬೆಳಕು ಒಂದು ವರ್ಷದಲ್ಲಿ ಅಂದರೆ 365.25 ದಿನಗಳಲ್ಲಿ ಚಲಿಸುವ ದೂರ. ಇದು 9.46×10^{12}ಕಿ.ಮೀ.)

ಕಪ್ಪು ಕುಳಿಯ ಅತಿ ಸಮೀಪದಲ್ಲಿ ವಿಶ್ವದ ಯಾವುದೇ ಆಕಾಶಕಾಯವು ಬಂದರೆ ಅದು ಸಮತಲವಾಗಿ ಹಿಂಡಿದಂತಾಗಿ, ಲಂಬವಾಗಿ ವಿಸ್ತರಿಸುತ್ತದೆ. ಎಲ್ಲಾ ಕಪ್ಪು ಕುಳಿಗಳೂ ತಮ್ಮ ಅಕ್ಷದ ಮೇಲೆ ವೇಗದಿಂದ ತಿರುಗುತ್ತವೆ. ಉದಾಹರಣೆಗೆ $GRS1915+105$ ಎಂಬ ಕಪ್ಪು ಕುಳಿಯು, ಅತಿ ವೇಗದಿಂದ ಅಂದರೆ ಸೆಕೆಂಡಿಗೆ 1000 ಬಾರಿ ತಿರುಗುತ್ತಿದೆ. ಸಾಮಾನ್ಯವಾಗಿ ಕ್ಷೀರಪಥದಂತಹ ಗ್ಯಾಲಾಕ್ಸಿಗಳ ಮಧ್ಯದಲ್ಲಿ ಬೃಹತ್ ದೈತ್ಯ ಕಪ್ಪು ಕುಳಿಗಳಿರುತ್ತವೆ. ಭೂಮಿಗೆ 26,000 ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದ ನಮ್ಮ ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯ ಮಧ್ಯದಲ್ಲಿರುವ 'ಸೆಗಿಟೇರಿಯಸ್ ಎ*' ಬೃಹತ್ ಕಪ್ಪು ಕುಳಿಯು ಸೂರ್ಯನ ದ್ರವ್ಯರಾಶಿಯ 4 ದಶಲಕ್ಷದಷ್ಟು ಇದೆ. ಒಂದು ವೇಳೆ ನಮ್ಮ ಸೂರ್ಯನನ್ನು, ಸೂರ್ಯನಷ್ಟೇ ದ್ರವ್ಯರಾಶಿಯ ಕಪ್ಪು ಕುಳಿಗೆ ಬದಲಾಯಿಸಿದಲ್ಲಿ ಸೂರ್ಯ ಮಂಡಲದ ಗ್ರಹಗಳ ಸ್ಥಾನವೇನೂ ಬದಲಾವಣೆಗೊಳ್ಳುವುದೇ ಇಲ್ಲ, ಆದರೆ ಸೂರ್ಯನಿಲ್ಲದೆ ಉಷ್ಣಾಂಶವು ಅತಿ ಕಡಿಮೆಯಾಗುತ್ತದೆ.

ಕಪ್ಪು ಕುಳಿ ಗುರುತಿಸುವಿಕೆ:

ಕಪ್ಪು ಕುಳಿಯ ಕಲ್ಪನೆಯನ್ನು ಮೊದಲು ಜಾನ್ ಮಿಚೆಲ್ ಎಂಬ ಭೂವಿಜ್ಞಾನಿ 1783ರಲ್ಲಿ ಪ್ರಸ್ತಾಪಿಸಿದ್ದಾರೆ. 1796ರಲ್ಲಿ ಪೀರೆ ಸೈಮನ್ ಎಂಬ ಗಣಿತವಿಜ್ಞಾನಿಯೂ ಕಪ್ಪು ನಕ್ಷತ್ರ ಎಂದು ತಮ್ಮ ಪುಸ್ತಕದಲ್ಲಿ ಉಲ್ಲೇಖಿಸಿದ್ದರು. ಆದರೆ ದ್ರವ್ಯರಾಶಿ ರಹಿತ ಬೆಳಕು ಗುರುತ್ವಶಕ್ತಿಯ ಪ್ರಭಾವಕ್ಕೆ ಹೇಗೆ ಒಳಗಾಗುವುದೆಂದು ಆಗ ಅರ್ಥವಾಗಿರಲಿಲ್ಲ.

1931ರಲ್ಲಿ ನೋಬೆಲ್ ಪ್ರಶಸ್ತಿ ವಿಜೇತ ಸುಬ್ರಹ್ಮಣ್ಯನ್ ಚಂದ್ರಶೇಖರ್‌ರವರು ಐನ್ಸ್ಟಿನ್ನರ ಸಾಮಾನ್ಯ ಸಾಪೇಕ್ಷತಾ ಸಿದ್ಧಾಂತದ ಆಧಾರದ ಮೇಲೆ, '1.44 ಸೌರ ದ್ರವ್ಯರಾಶಿಗಳಿಗಿಂತ ಹೆಚ್ಚಿನ ದ್ರವ್ಯರಾಶಿಯಿರುವ ನಕ್ಷತ್ರಗಳು ತಮ್ಮ ಅಂತಿಮ ಘಟ್ಟದಲ್ಲಿ ಬಿಳಿಕುಬ್ಜ ಮತ್ತು ಅದಕ್ಕೂ ಹೆಚ್ಚಿನ ದ್ರವ್ಯರಾಶಿಯ ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರ ಅಥವಾ ಅದಕ್ಕೂ ಮಿಗಿಲಾದವು ಕಪ್ಪು ಕುಳಿಯಾಗಿ ಕುಸಿಯುತ್ತವೆ' ಎಂದು ಲೆಕ್ಕ ಹಾಕಿದ್ದಾರೆ.

ಬ್ಲಾಕ್ ಹೋಲ್ ($Black\ Hole$) (ಕಪ್ಪು ಕುಳಿ ಅಥವಾ ಕೃಷ್ಣ ರಂಧ್ರ) ಪದವನ್ನು ಜಾನ್ ವೀಲರ್ 1967ರಲ್ಲಿ ಮೊದಲು ತಮ್ಮ ಉಪನ್ಯಾಸ ಸಂದರ್ಭದಲ್ಲಿ ಉಪಯೋಗಿಸಿದ ನಂತರ ಆ ಪದವೇ ಬಳಕೆಗೆ ಬಂದಿದೆ. ಕಪ್ಪು ಕುಳಿಯು ಅದರ ಹೆಸರೇ ಸೂಚಿಸುವಂತೆ ತನ್ನಿಂದ ಯಾವ ಬೆಳಕನ್ನೂ ಹೊರಬಿಡಲಾರದೆ ಕಪ್ಪಾಗಿರುತ್ತದೆ. ಆದ್ದರಿಂದಲೇ ಬಾಹ್ಯಾಕಾಶದಲ್ಲಿ ಇದರ ಅದೃಶ್ಯ ಆಕೃತಿಯನ್ನು ಗುರುತಿಸುವುದು ಕಷ್ಟ ಸಾಧ್ಯವೇ ಆಗಿದೆ. ಇವುಗಳ ಸುತ್ತಮುತ್ತ ಪರಿಭ್ರಮಣೆ ಮಾಡುತ್ತಿರುವ ನಕ್ಷತ್ರ ಮತ್ತು ಇತರ ಆಕಾಶ ಕಾಯಗಳ ಚಲನೆಯನ್ನು ಅಧ್ಯಯನ ಮಾಡುವುದರಿಂದ ಕಪ್ಪು ಕುಳಿಗಳ ಇರುವಿಕೆಯನ್ನು ಪತ್ತೆಮಾಡಬಹುದು. ನಕ್ಷತ್ರಗಳು ಕಪ್ಪು ಕುಳಿ ಸಮೀಪದಲ್ಲಿ ಹಾದು ಹೋದಾಗ ಅವುಗಳ ಮೇಲ್ಮೈಯಲ್ಲಿ ತರಂಗಗಳ ಕಂಪನಗಳು ಉಂಟಾಗುತ್ತವೆ. ಇದಲ್ಲದೆ ಕೆಲವು ಬಾರಿ ಕಪ್ಪು ಕುಳಿಯು ಅದರ ಸಮೀಪ ಬಂದ ನಕ್ಷತ್ರಗಳನ್ನು ನುಂಗುತ್ತಿರುವಲ್ಲಿ, ಅವುಗಳಿಂದ ಅನಿಲವು ಒಳಮುಖವಾಗಿ ಬೀಳುತ್ತಿರುವಾಗ ಹೆಚ್ಚು ಪ್ರಮಾಣದ ವಿಕಿರಣವನ್ನು ಹೊರಸೂಸುವುದನ್ನು ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕ ಮತ್ತು ಭೂಮಿಯ ದೂರದರ್ಶಕದಿಂದಲೂ ವೀಕ್ಷಿಸಿ ಕಪ್ಪು ಕುಳಿಯ ಇರುವಿಕೆಯನ್ನು ಪತ್ತೆಹಚ್ಚಿದ್ದಾರೆ.

'ಬ್ಲಾಕ್ ಹೋಲ್' ಎಂಬ ಪದವು 18ನೇ ಶತಮಾನದಲ್ಲೇ ಭಾರತದ ಚರಿತ್ರೆಯಲ್ಲಿ ಉಲ್ಲೇಖವಾಗಿದೆ, ಆದರೆ ಬೇರೆಯದೇ ಸಂದರ್ಭದಲ್ಲಿ. ಅದೇ 'ಬ್ಲಾಕ್ ಹೋಲ್ ಆಫ್ ಕಲ್ಕತ್ತ'. 1756ರಲ್ಲಿ ಬೆಂಗಾಲ್‌ನ ನವಾಬನಾಗಿದ್ದ ಸಿರಾಜದ್ದೌಲನ ಆಜ್ಞೆಗೆ ವಿರುದ್ಧವಾಗಿ ಬ್ರಿಟೀಷರು ಕಲ್ಕತ್ತಾದಲ್ಲಿ ಕೋಟೆ ಕಟ್ಟಲು ಪ್ರಾರಂಭಿಸಿದಾಗ ನವಾಬನು ಸಿಟ್ಟಾಗಿ ಸುಮಾರು 200 ಜನ ಬ್ರಿಟೀಷರನ್ನು ಇಕ್ಕಟ್ಟಾದ ಕೋಣೆಯಲ್ಲಿ ಒಂದು ದಿನ ಪೂರ್ತಿ ಕೂಡಿಹಾಕಿದ್ದರು. ಆ ಕೋಣೆಯು 'ಬ್ಲಾಕ್ ಹೋಲ್' ಎಂದೇ ಪ್ರಸಿದ್ಧವಾಯಿತು.

ಕಪ್ಪು ಕುಳಿಯ ಗುಣಲಕ್ಷಣಗಳು:

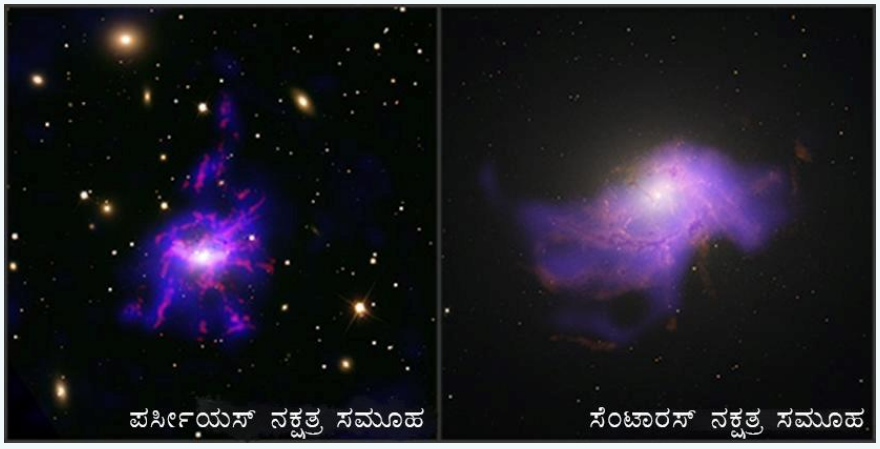
ಕಪ್ಪು ಕುಳಿಗಳು 'ವರ್ಮ್ ಹೋಲ್' ಆಗಿರುವುದಿಲ್ಲ. ಅಂದರೆ ಕಪ್ಪು ಕುಳಿಯು ಯಾವ ದ್ರವ್ಯವನ್ನೂ ಬೇರೆ ಆಯಾಮದ ವಿಶ್ವಕ್ಕೆ ಹೋಗಲು ಬಿಡುವುದಿಲ್ಲ. ಹಾಸ್ಯಕ್ಕಾಗಿ 'ಬ್ಲಾಕ್ ಹೋಲ್‌ಗೆ ಇಳಿಯುವುದು ಜೀವನದಲ್ಲಿ ಒಮ್ಮೆ ಮಾತ್ರ ಅನುಭವಿಸಬೇಕಷ್ಟೆ'. 'ಬ್ಲಾಕ್ ಹೋಲ್‌ಗೆ ರಹಸ್ಯಗಳನ್ನು ಹೇಳಿದರೆ ಯಾರಿಗೂ ಬಿಟ್ಟುಕೊಡುವುದಿಲ್ಲ'! ಎನ್ನುತ್ತಾರೆ.

ಕಪ್ಪು ಕುಳಿಯ ಗುರುತ್ವ ಶಕ್ತಿಯು ಅದೇ ದ್ರವ್ಯರಾಶಿಯ ಬೇರೆ ದ್ರವ್ಯದಂತೆಯೇ ಇರುತ್ತದೆ. ಕಪ್ಪು ಕುಳಿಗಳು ಅತಿ ಕಡಿಮೆ ಉಷ್ಣಾಂಶದಿಂದ ಕೂಡಿರುತ್ತವೆ, ಆದರೆ ಅದಕ್ಕೇ ಹೊರಚಾಚಿಕೊಂಡಿರುವ ಈವೆಂಟ್ ಹೊರೈಜನ್ ಅತೀವ ಉಷ್ಣಾಂಶದಿಂದ ಕೂಡಿರುತ್ತದೆ.

ಕಪ್ಪು ಕುಳಿಗಳು ಆಕ್ರಮಿಸುವ ಸ್ಥಳ ವಿಜ್ಞಾನಿಗಳ ಪ್ರಕಾರ, ಸುಮಾರು 300 ಸೌರ ದ್ರವ್ಯರಾಶಿಯ ಕಪ್ಪು ಕುಳಿಯು ಕೇವಲ 900 ಕಿ.ಮೀ.ಗಳ ತ್ರಿಜ್ಯವನ್ನು ಹೊಂದಿರುತ್ತದೆ.

ಚಂದ್ರ ಎಕ್ಸ್–ರೇ ದೂರದರ್ಶಕದ ವೀಕ್ಷಣೆಯಂತೆ, ಕಪ್ಪು ಕುಳಿಗಳು ಅನಿಲವನ್ನು ತಣ್ಣಗಾಗಿಸಿ ಆ ಉಷ್ಣತೆಯನ್ನು ತಾವೇ ಪೋಷಿಸಿಕೊಳ್ಳುತ್ತವೆ. ಅಂದರೆ ತಮಗೆ ಬೇಕಾದ ಉಷ್ಣತೆಯನ್ನು ತಾವೇ ತಯಾರಿಸಿಕೊಳ್ಳುತ್ತವೆ. ಇದನ್ನು ಕೆಳಗಿನ ಉದಾಹರಣೆಯಿಂದ ತಿಳಿಯಬಹುದು:

ಚಂದ್ರ ಎಕ್ಸ್–ರೇ ವೀಕ್ಷಣಾಲಯ ಮತ್ತು ಚಿಲಿಯಲ್ಲಿರುವ 'ದಿ ವೆರಿ ಲಾರ್ಜ್ ಟೆಲಿಸ್ಕೋಪ್' (ವಿ. ಎಲ್. ಟಿ) ವರದಿಯಂತೆ ಏಳು ಗ್ಯಾಲಾಕ್ಸಿಗಳ ಗೊಂಚಲಿನ ಗುಂಪಿನಲ್ಲಿರುವ ಪರ್ಸಿಯಸ್ ಮತ್ತು ಸೆಂಟಾರಸ್ ಗೊಂಚಲಿನಲ್ಲಿ ವಿಶ್ವದ ಅತಿ ದೊಡ್ಡ ದೊಡ್ಡ ಗ್ಯಾಲಾಕ್ಸಿಗಳು ಇವೆ (ಚಿತ್ರ 2). ಅವುಗಳಲ್ಲಿ 10 ಲಕ್ಷದಿಂದ 100 ಶತಕೋಟಿ ಸೌರ ದ್ರವ್ಯರಾಶಿಯ ಕಪ್ಪು ಕುಳಿಗಳಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಇವುಗಳಿಂದ ಬರುವ ಬಿಸಿ ಅನಿಲದ ಜೆಟ್‌ಗಳನ್ನು ತಾವೇ ಸೇವಿಸುತ್ತವೆ. ಇದರ ಪ್ರಕಾರ ಕೆಲವು ತಂತುಗಳಲ್ಲಿರುವ ಬಿಸಿ ಅನಿಲವು ಕಪ್ಪು ಕುಳಿಗಳಿಗೆ ಆಹಾರವನ್ನು ನೀಡಲು ಗ್ಯಾಲಾಕ್ಸಿಗಳ ಕೇಂದ್ರಗಳಿಗೆ ಹರಿಯುತ್ತವೆ. ಈ ಹೊರಹರಿವಿನಿಂದ ಆಸ್ಫೋಟವುಂಟಾಗುತ್ತದೆ. ಇದರಿಂದ ಉಂಟಾದ ಶಾಖವು ಕಪ್ಪು ಕುಳಿಗಳಿಗೆ ಆಹಾರವಾಗುತ್ತದೆ. ಚಿತ್ರ 2ರಲ್ಲಿರುವಂತೆ, ಪರ್ಸಿಯಸ್ ಮತ್ತು ಸೆಂಟಾರಸ್ ಚಿತ್ರದಲ್ಲಿರುವ ನೀಲಿ ಬಣ್ಣವು ಎಕ್ಸ್–ಕಿರಣವನ್ನು ಪ್ರತಿನಿಧಿಸಿದರೆ, ತಣ್ಣಗಿರುವ ತಂತುಗಳು ಕೆಂಪು ಬಣ್ಣವನ್ನು ಪ್ರತಿನಿಧಿಸುತ್ತದೆ.



ಚಿತ್ರ 2 ಚಂದ್ರ ಎಕ್ಸ್–ರೇ ದೂರದರ್ಶಕದಿಂದ ತೆಗೆದ ವಿಶ್ವದ ಅತಿ ದೊಡ್ಡ ದೊಡ್ಡ ಗ್ಯಾಲಾಕ್ಸಿಗಳು.

ಚಿತ್ರ 3 ಆಕ್ಟೀವ್ ಗ್ಯಾಲಾಕ್ಟಿಕ್ ನ್ಯೂಕ್ಲಿಯಸ್

ಆಕ್ಟೀವ್ ಗ್ಯಾಲಾಕ್ಟಿಕ್ ನ್ಯೂಕ್ಲಿಯಸ್: ಬೃಹತ್ ಗ್ಯಾಲಾಕ್ಸಿಗಳ ಮಧ್ಯದಲ್ಲಿ ಕಪ್ಪು ಕುಳಿಗಳಿದ್ದು ಅವುಗಳನ್ನು ನಕ್ಷತ್ರಗಳ ಸಾವಿನ ಕೋಣೆಯೆಂದೇ ಕರೆಯುವರು. ಧೂಳು ಮತ್ತು ಅನಿಲಗಳು ಆ ಕಪ್ಪು ಕುಳಿಯೊಳಗೆ ಬೀಳುವಾಗ ಅವುಗಳಿಂದ ಹೊರಸೂಸುವ ಬೆಳಕು, ರೇಡಿಯೋ, ಗಾಮಾ ಮುಂತಾದ ವಿದ್ಯುತ್–ಕಾಂತ ಕಿರಣಗಳನ್ನು ಹೊರಸೂಸುತ್ತಿರುವುದು ಶತಕೋಟಿ ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದವರೆಗೂ ಕಾಣುತ್ತವೆ. ಇದಕ್ಕೆ 'ಆಕ್ಟೀವ್‌ಗ್ಯಾಲಾಕ್ಟಿಕ್ ನ್ಯೂಕ್ಲಿಯಸ್' ಎನ್ನುತ್ತಾರೆ (ಚಿತ್ರ 3).

ಕಪ್ಪು ಕುಳಿಗಳ ವಿಧಗಳು

ನಕ್ಷತ್ರಗಳಿಂದಾದ ಕಪ್ಪುಕುಳಿಗಳು:

ಸೌರದ್ರವ್ಯರಾಶಿಯ ಎಂಟು ಪಟ್ಟು ಅಥವಾ ಅದಕ್ಕಿಂತ ಹೆಚ್ಚು ದ್ರವ್ಯರಾಶಿಯುಳ್ಳ ನಕ್ಷತ್ರಗಳು ತಮ್ಮ ಇಂಧನವನ್ನು ಉರಿಸಿ ಪೂರೈಸಿದ ನಂತರ ಒಳಗಿನ ಒತ್ತಡವು, ಗುರುತ್ವವನ್ನು ಎದುರಿಸಲಾರದೆ ಕುಸಿತವನ್ನು ಕಂಡು ಸೂಪನೋವಾ ಆಗಿ ಸಿಡಿಯುತ್ತವೆ. ಮಧ್ಯಭಾಗದ ದ್ರವ್ಯರಾಶಿಯು ಮಿತಿಗಿಂತ ಕಡಿಮೆ ಇದ್ದರೆ ಅಂಥಹವು ಸುಮಾರು 20 ಮೈಲಿ ವ್ಯಾಸವುಳ್ಳ ಅತಿಸಾಂದ್ರತೆಯುಳ್ಳ 'ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರ'ಗಳಾಗುತ್ತವೆ. 20 ಅಥವಾ ಅದಕ್ಕಿಂತ ಹೆಚ್ಚು ಸೌರದ್ರವ್ಯರಾಶಿ ಹೊಂದಿದ್ದರೆ ಅಂತಹ ನಕ್ಷತ್ರಗಳ ಮಧ್ಯಭಾಗವು ಕುಸಿತವನ್ನು ಕಂಡು 'ನಕ್ಷತ್ರಗಳ ದ್ರವ್ಯರಾಶಿಯಿಂದಾದ 'ಕಪ್ಪುಕುಳಿ'ಯಾಗಿ ರೂಪುಗೊಳ್ಳುತ್ತವೆ. ಈ ಕಪ್ಪುಕುಳಿಗಳು ತಮ್ಮ ಅಕ್ಕ ಪಕ್ಕಗಳಲ್ಲಿರುವ ನಕ್ಷತ್ರ ಮತ್ತು ಕಪ್ಪು ಕುಳಿಗಳೊಡನೆ ಘರ್ಷಣೆಗೊಳಗಾಗಿ ಅವುಗಳನ್ನೂ ತಮ್ಮ ಗುರುತ್ವಾಕರ್ಷಣೆಯಿಂದ ವಿಲೀನಗೊಳಿಸಿಕೊಂಡು ತಮ್ಮ ದ್ರವ್ಯರಾಶಿಯನ್ನು ಹೆಚ್ಚಿಸಿಕೊಳ್ಳುತ್ತವೆ. ಸಾಮಾನ್ಯವಾಗಿ ಯುಗಳ ನಕ್ಷತ್ರಗಳಲ್ಲಿ ಹೆಚ್ಚು ದ್ರವ್ಯರಾಶಿಯುಳ್ಳ ಒಂದು ತಮ್ಮ ಅಂತಿಮ ಘಟ್ಟದಲ್ಲಿ ನಕ್ಷತ್ರಗಳ ಕಪ್ಪುಕುಳಿಯಾಗಿ ಹೊರಹೊಮ್ಮುತ್ತವೆ. ಇವುಗಳು ಎಕ್ಸ್–ಕಿರಣವನ್ನು ಹೊರಹೊಮ್ಮುವ ಯುಗಳಗಳೂ ಆಗಿರಬಹುದು. ನಮ್ಮ ಕ್ಷೀರಪಥ ಒಂದರಲ್ಲೇ 100 ದಶಲಕ್ಷ ಇಂತಹ ಕಪ್ಪುಕುಳಿಗಳು ಇರಬಹುದೆಂದು ವಿಜ್ಞಾನಿಗಳ ಅಭಿಮತ.

ಬೃಹತ್ ಕಪ್ಪು ಕುಳಿಗಳು (*Supermassive Black holes*):

ಪ್ರತಿಯೊಂದು ಗ್ಯಾಲಾಕ್ಸಿಯ ಕೇಂದ್ರದಲ್ಲೂ ಒಂದು ಅಗಾಧವಾದ ಕಪ್ಪು ಕುಳಿ ಇರುತ್ತದೆ. ಇವುಗಳು ಸೂರ್ಯನ ದ್ರವ್ಯರಾಶಿಯ ಸಾವಿರಾರು ಶತಕೋಟಿಯಷ್ಟು ಇರುತ್ತವೆಯೆಂದು ವಿಜ್ಞಾನಿಗಳು ಲೆಕ್ಕಹಾಕಿದ್ದಾರೆ.

1931ರಲ್ಲಿ ನಮ್ಮ ಕ್ಷೀರಪಥಗ್ಯಾಲಾಕ್ಸಿಯ ಮಧ್ಯದಲ್ಲಿರುವ ಸಗಿಟೇರಿಯಸ್ ನಕ್ಷತ್ರಪುಂಜದಲ್ಲಿ 'ಸಗಿಟೇರಿಯಸ್ ಎ*' ಬೃಹತ್ ದೈತ್ಯ ಕಪ್ಪು ಕುಳಿಯನ್ನು ಅವಗೆಂಪು ಕಿರಣ ದೂರದರ್ಶಕದಲ್ಲಿ ಕಂಡುಹಿಡಿಯಲಾಯಿತು. 6 ನಕ್ಷತ್ರಗಳು ಈ ಕಪ್ಪು ಕುಳಿಯನ್ನು ಸುತ್ತುತ್ತಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಇದು ಶಕ್ತಿಯುತವಾದ ಎಕ್ಸ್–ರೇ, ಗಾಮಾ ಮುಂತಾದ ವಿದ್ಯುತ್ಕಾಂತ ವಿಕಿರಣಗಳನ್ನು ಹೊರಹಾಕುತ್ತಿದೆಯೆಂದು ವಿಜ್ಞಾನಿಗಳ ವಿಶ್ಲೇಷಣೆ.

10^5ಗೂ ಹೆಚ್ಚು ಸೌರದ್ರವ್ಯರಾಶಿಯವು, ಬೃಹತ್ ಕಪ್ಪು ಕುಳಿ(*massive Black Hole*)ಗಳ ವರ್ಗಕ್ಕೆ ಸೇರಿವೆ. ಕೆಲವು ಅನೇಕ ಶತಕೋಟಿ ಸೌರದ್ರವ್ಯರಾಶಿಯನ್ನೊಳಗೊಂಡಿರುತ್ತವೆ. ಈ ಬಗೆಯ ಕಪ್ಪು ಕುಳಿಗಳ ಈವೆಂಟ್ ಹೊರೈಸನ್ ಸಮೀಪದಲ್ಲಿ ಉಬ್ಬರವಿಳಿತದ ಬಲವು (*Tidal force*) ಕಡಿಮೆ ಇರುತ್ತದೆ. (ಉಬ್ಬರವಿಳಿತದ ಬಲವು ಯಾವಾಗಲೂ ಕಪ್ಪು ಕುಳಿಯ ದ್ರವ್ಯರಾಶಿಯ ವಿಲೋಮ ಅನುಪಾತದಲ್ಲಿರುತ್ತದೆ). ನಮ್ಮ ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯ ಮಧ್ಯದಲ್ಲಿ ಇರುವ ಸಗಿಟೇರಿಯಸ್ ಎ* ಬೃಹತ್ ಕಪ್ಪು ಕುಳಿಯು 40 ದಶಲಕ್ಷ ಸೌರ ದ್ರವ್ಯರಾಶಿಯನ್ನು ಹೊಂದಿದೆ.

ಕೆಲವು ಕಪ್ಪು ಕುಳಿಗಳು 5 ಶತಕೋಟಿಗೂ (5×10^9) ಹೆಚ್ಚು ಸೌರದ್ರವ್ಯರಾಶಿಯನ್ನು ಹೊಂದಿರುತ್ತವೆ. ಅವುಗಳನ್ನು ಅತಿ ಬೃಹತ್ ಕಪ್ಪು ಕುಳಿಗಳೆನ್ನುವರು (*Super massive Black holes*). ಇಂತಹವುಗಳನ್ನು $NGC6166$ ಮತ್ತು $NGC4889$ ಗ್ಯಾಲಾಕ್ಸಿಗಳಲ್ಲಿ ಕಾಣಬಹುದೆಂದು ಖಗೋಳವಿಜ್ಞಾನಿಗಳ ಸಂಶೋಧನೆಯಿಂದ ತಿಳಿದುಬಂದಿದೆ.

ಮಧ್ಯಮ ದ್ರವ್ಯರಾಶಿಯ ಕಪ್ಪು ಕುಳಿಗಳು: (*Intermediate – mass black holes*):

ನಕ್ಷತ್ರಗಳಿಂದಾದ ಕಪ್ಪು ಕುಳಿ ಮತ್ತು ಬೃಹತ್ ಕಪ್ಪು ಕುಳಿಗಳಿಗೂ ಮಧ್ಯದಲ್ಲಿರುವ ದ್ರವ್ಯರಾಶಿಯ ಕಪ್ಪು ಕುಳಿಗೆ ಮಧ್ಯಮ ದ್ರವ್ಯರಾಶಿ ಕಪ್ಪು ಕುಳಿಯೆನ್ನುತ್ತಾರೆ. ಇವು ನಕ್ಷತ್ರಗಳಿಂದಾದ ಕಪ್ಪು ಕುಳಿಗಳ ಘರ್ಷಣೆಯಿಂದ ಉಂಟಾಗಿರಬಹುದೆಂದು ವಿಜ್ಞಾನಿಗಳು ಹೇಳುತ್ತಾರೆ.

2009ರಲ್ಲಿ $HLX-1$ಎಂಬ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ, ನಕ್ಷತ್ರಗಳ ಸಮೂಹವನ್ನು ಹೊಂದಿರುವ ಒಂದು ಮಧ್ಯಂತರ ಕಪ್ಪು ಕುಳಿಯನ್ನು ಗುರುತಿಸಿದ್ದಾರೆ.

$3XMMJ2150224-055108$ ಎಂಬ ಮಧ್ಯಮ ದ್ರವ್ಯರಾಶಿ ಕಪ್ಪು ಕುಳಿಯನ್ನು, 2020ರಲ್ಲಿ ಹಬಲ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕದಿಂದ ಕಂಡುಹಿಡಿಯಲಾಗಿದೆ. ಇದು 50,000 ಸೌರದ್ರವ್ಯರಾಶಿಯಷ್ಟಿದ್ದು ಎಕ್ಸ್–ಕಿರಣಗಳನ್ನು ಹೊರಸೂಸುತ್ತಿದೆ. ಇದು 740 ದಶಲಕ್ಷ ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿರುವ ಅಕ್ವೇರಿಯಸ್ ನಕ್ಷತ್ರಪುಂಜದಲ್ಲಿದೆ.

ಇತ್ತೀಚೆಗೆ ಖಗೋಳವಿಜ್ಞಾನಿಗಳಿಂದ ಈ ಮಧ್ಯಮ ದ್ರವ್ಯರಾಶಿ ಕಪ್ಪು ಕುಳಿಗಳನ್ನು ಗುರುತಿಸುವಲ್ಲಿ ಹೆಚ್ಚು ಸಂಶೋಧನೆ ನಡೆಯುತ್ತಿದ್ದು, 2024ರಲ್ಲಿ ಒಮೆಗಾ ಸೆಂಚುರಿ ನಕ್ಷತ್ರ ಪುಂಜದಲ್ಲಿ 8200 ಸೌರ ದ್ರವ್ಯರಾಶಿಯ ಮಧ್ಯಂತರ ದ್ರವ್ಯರಾಶಿ ಕಪ್ಪು ಕುಳಿ ಇರುವ ಸಾಧ್ಯತೆಯನ್ನು ಗುರುತಿಸಿದ್ದಾರೆ.

ಈ ವರ್ಗಕ್ಕೆ ಸೇರಿದ ಕಪ್ಪು ಕುಳಿಗಳು ಸೂರ್ಯನ ದ್ರವ್ಯರಾಶಿಯ $10^2 - 10^5$ ರಷ್ಟು ಇರುತ್ತವೆ. ಒಂದು ನಕ್ಷತ್ರವು ಕುಸಿದು ಈ ಬಗೆಯ ಕಪ್ಪು ಕುಳಿಯೇರ್ಪಡಲು ಸಾಧ್ಯವಿಲ್ಲ. ಇತ್ತೀಚಿನ ಸಿದ್ಧಾಂತಗಳು ಮಧ್ಯಂತರ ದ್ರವ್ಯರಾಶಿ ಕಪ್ಪು ಕುಳಿಗಳ ರಚನೆಗೆ ಕಾರಣವಾಗುವ ಬೃಹತ್ ನಕ್ಷತ್ರಗಳು, ಅಂತರ ತಾರಾ ವಲಯದಲ್ಲಿ ಓಡುತ್ತಿರುವ ನಕ್ಷತ್ರಗಳ ಘರ್ಷಣೆಯಿಂದ ಅಥವಾ ಅತಿ ದಟ್ಟವಾದ ನಕ್ಷತ್ರಗಳ ಸಮೂಹದಲ್ಲಿರುವ ಚಿಕ್ಕ ಚಿಕ್ಕ ನಕ್ಷತ್ರದ ಕಪ್ಪು ಕುಳಿಗಳ ಘರ್ಷಣೆಯಿಂದಲೂ ರೂಪಿತವಾಗಿರಬಹುದೆನ್ನುತ್ತಾರೆ ವಿಜ್ಞಾನಿಗಳು. 2004ರಲ್ಲಿ $GCIRS\ 13E$ ಎಂಬ ಮಧ್ಯಂತರ ಕಪ್ಪು ಕುಳಿಯನ್ನು ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ ಧನುರಾಶಿಯಿಂದ ಮೂರು ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿ ಕಂಡುಹಿಡಿದಿದ್ದಾರೆ. 1300 ಸೌರದ್ರವ್ಯರಾಶಿಗಳ ಈ ಕಪ್ಪು ಕುಳಿಯು ಏಳು ನಕ್ಷತ್ರಗಳ ಸಮೂಹದಲ್ಲಿದೆ.

ಭೂಮಿಗೆ 17,700 ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿರುವ ಪ್ರಕಾಶಮಾನವಾದ ಗೋಳಾಕಾರದ ನಕ್ಷತ್ರಗಳ ಸಮೂಹವಾದ $(globular\ star\ cluster)$ 'ಒಮೆಗಾ ಸೆಂಟೌರಿ' ಇದೆ. ಇದರ ಮಧ್ಯದಲ್ಲಿ 8200 ಸೌರ ದ್ರವ್ಯರಾಶಿಯುಳ್ಳ ಮಧ್ಯಮ ದ್ರವ್ಯರಾಶಿಯ ಕಪ್ಪು ಕುಳಿಯು ಮಾರ್ಪಟ್ಟಿರುವುದಾಗಿ, ಖಗೋಳ ವಿಜ್ಞಾನಿಗಳ ಪರೀಕ್ಷೆಯಿಂದ ತಿಳಿದುಬಂದಿದೆ. 2024ರಲ್ಲಿ ಇದರ ಅನೇಕ ಚಿತ್ರಣಗಳನ್ನು ನಾಸಾದ ಹಬಲ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕವು ಕಳುಹಿಸಿದೆ. ಇದು ಭೂಮಿಗೆ ಅತಿ ಹತ್ತಿರದಲ್ಲಿರುವ ಮಧ್ಯಮ ದ್ರವ್ಯರಾಶಿಯ ಕಪ್ಪು ಕುಳಿಯಾಗಿದೆ.

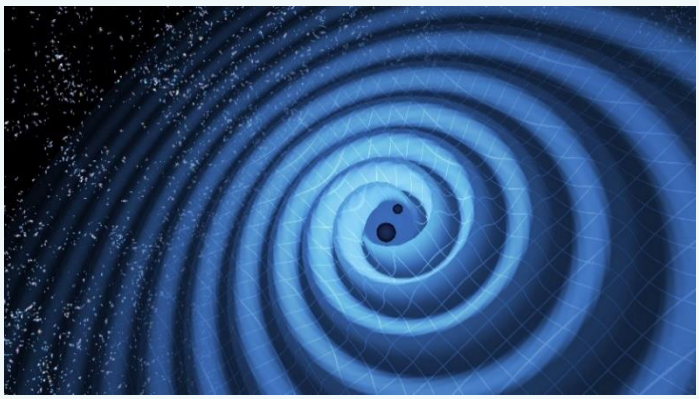
ಎಕ್ಸ್–ರೇಗಳನ್ನು ಹೊರಗೊಮ್ಮುವ ಯುಎಲ್–ಎಕ್ಸ್$(Ultraluminous\ X-ray)$ ವರ್ಗಕ್ಕೆ ಸೇರಿದ ಕಪ್ಪು ಕುಳಿಗಳು ಮಧ್ಯಮ ದ್ರವ್ಯರಾಶಿಯದಾಗಿರುತ್ತವೆ. ನ್ಯುಸ್ಟಾರ್ $(NUSTAR)$, ಚಂದ್ರ ಮತ್ತಿತರ ದೂರದರ್ಶಕಗಳು, 13 ಶತಕೋಟಿ ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿರುವ ಸಿರ್‌ಸಿನಸ್ ಸ್ಪೈರಲ್ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿರುವ ಈ ಬಗೆಯ ಕಪ್ಪು ಕುಳಿಗಳ ದ್ರವ್ಯರಾಶಿ, ಮತ್ತಿತರ ಲಕ್ಷಣಗಳನ್ನು ಕಂಡುಹಿಡಿಯುತ್ತಿವೆ. ಈ ಬಗೆಯ ಕಪ್ಪು ಕುಳಿಗಳು ಸಜಾತಿ ಭಕ್ಷಕ ಗುಣಗಳನ್ನು ಪಡೆದಿರುತ್ತವೆ.

ಕಪ್ಪು ಕುಳಿಗಳ ಘರ್ಷಣೆಯಿಂದ ಏರ್ಪಟ್ಟ ಗುರುತ್ವಾಕರ್ಷಣ ಅಲೆ:

ಎರಡು ನಕ್ಷತ್ರಗಳಿಂದ ರೂಪಗೊಂಡ ಕಪ್ಪು ಕುಳಿಗಳು ಒಂದಕ್ಕೊಂದು ಘರ್ಷಣೆಗೊಳಗಾಗಿ ಮಧ್ಯಮ ದ್ರವ್ಯರಾಶಿಯ ಕಪ್ಪು ಪುಳಿಯೇರ್ಪಡಲು ಸಾಧ್ಯವಿದೆ. ಉದಾಹರಣೆಗೆ 2019ರಲ್ಲಿ ಸೂರ್ಯನ ದ್ರವ್ಯರಾಶಿಯ 85 ಮತ್ತು 65ರ ಎರಡು ಕಪ್ಪು ಕುಳಿಗಳು ಘರ್ಷಣೆಗೊಂಡು 142 ಸೌರ ದ್ರವ್ಯರಾಶಿಯುಳ್ಳ ಕಪ್ಪು ಕುಳಿಯಾಗಿ ವಿಲೀನಗೊಂಡವು. ಇದು ಭೂಮಿಯಿಂದ 53 ದಶಲಕ್ಷ ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿದೆ. ಈ ಕಪ್ಪು ಕುಳಿಗಳ ವಿಲೀನತೆಯನ್ನು ಭಾರತದ ವಿಜ್ಞಾನಿಗಳೂ ಸೇರಿ ಅಂತರರಾಷ್ಟ್ರೀಯ ಖಗೋಳವಿಜ್ಞಾನಿಗಳ ತಂಡವು, ಲಿಗೊ ಮತ್ತು ವಿರ್ಗೋ ಸಹಯೋಗದೊಂದಿಗೆ ಗುರುತ್ವಾಕರ್ಷಣ ಅಲೆಗಳನ್ನು ವೀಕ್ಷಿಸುವುದರ ಮೂಲಕ ದೃಢಪಡಿಸಿದ್ದಾರೆ (ಚಿತ್ರ 4).

ಆದಿಸ್ವರೂಪದ ಕಪ್ಪು ಕುಳಿಗಳು:

ವಿಜ್ಞಾನಿಗಳ ಸಿದ್ಧಾಂತದ ಪ್ರಕಾರ ವಿಶ್ವದ ಹುಟ್ಟಿನ ಮೊದಲನೇ ಸೆಕೆಂಡಿನಲ್ಲಿ ಆದಿಸ್ವರೂಪದ ಕಪ್ಪು ಕುಳಿಗಳು ರೂಪಿತವಾಗಿವೆ. ಆಗ ಅತಿ ಹಗುವಾದವುಗಳಿಂದ ಹಿಡಿದು 100,000 ಸೌರ ದ್ರವ್ಯರಾಶಿಯಷ್ಟು ಸಾಂದ್ರವುಳ್ಳ ಆಕಾಶ ಕಾಯಗಳು ರೂಪಿತವಾಗಿ ತಕ್ಷಣ ವಿಸ್ತರಿಸಿದ ಪರಿಣಾಮವಾಗಿ ವಿಶ್ವವು ತಣ್ಣಗಾಯಿತು. ಈ ಅತಿ ಸಾಂದ್ರವುಳ್ಳ ಆಕಾಶಕಾಯಗಳು ಆದಿಸ್ವರೂಪದ ಕಪ್ಪುಕುಳಿಗಳಾದವು, ಕಡಿಮೆ ದ್ರವ್ಯರಾಶಿಯ ಕಪ್ಪು ಕುಳಿಗಳು ಆವಿಯಾಗಿ ಹೋಗಿವೆ. 13.8 ಶತಕೋಟಿ ವರ್ಷಗಳ ಹಿಂದೆ ರೂಪಿತವಾಗಿರಬಹುದಾದ ಈ ದೈತ್ಯ ಆದಿಸ್ವರೂಪದ ಕಪ್ಪುಕುಳಿಗಳು ಇರುವುದು ಇನ್ನೂ ಸೈದ್ಧಾಂತಿಕವಾಗಿಯೇ ಇದೆ.



ಚಿತ್ರ 4 2019ರಲ್ಲಿ ಕಪ್ಪು ಕುಳಿಗಳ ಘರ್ಷಣೆಯಿಂದ ಏರ್ಪಟ್ಟ ಗುರುತ್ವಾಕರ್ಷಣ ಅಲೆ

ಸುಮಾರು 10 ಶತಕೋಟಿ ಜ್ಯೋತಿರ್ವರ್ಷಗಳ ದೂರದಲ್ಲಿರುವ ಗ್ಯಾಲಾಕ್ಸಿಗಳಿಂದ ಬರುತ್ತಿರುವ ರೇಡಿಯೋ ಅಲೆಗಳು ನಮಗೆ ತಲುಪಲು 10 ಶತಕೋಟಿ ವರ್ಷಗಳನ್ನು ತೆಗೆದುಕೊಂಡಿದೆ. ಅಂದರೆ ನಾವು ನೋಡುತ್ತಿರುವುದು 10 ಶತಕೋಟಿ ವರ್ಷಗಳ ರೇಡಿಯೋ ಅಲೆಗಳು ಎಂದು ಅರ್ಥ. ಇವುಗಳ ಅಧ್ಯಯನದಿಂದ ಸಂಶೋಧಕರ ಸಿದ್ಧಾಂತದ ಅಂಶಗಳು ಹೀಗಿವೆ. 'ಆಗಸದಲ್ಲಿ ಮೊದಲ ನಕ್ಷತ್ರ ಉದಯವಾಗುವ ಮುಂಚಿತವಾಗಿ ಮೋಡದಂತಹ ನಕ್ಷತ್ರಗಳ ಪ್ರಭಾವಲಯ ಸೃಷ್ಟಿಯಾಗಿ ನಂತರದಲ್ಲಿ, ಸುಮಾರು ಸೂರ್ಯನ 20ರಷ್ಟು ದ್ರವ್ಯರಾಶಿಯ ಕಪ್ಪು ಕುಳಿ ರೂಪಿತವಾಗಿರಬಹುದು'. ಮತ್ತೊಂದು ಸಿದ್ಧಾಂತದ ಪ್ರಕಾರ 'ಈ ಮೊದಲ ನಕ್ಷತ್ರಗಳ ಪ್ರಭಾವಲಯವು ಸೂರ್ಯನ 10,000ರಷ್ಟು ದ್ರವ್ಯರಾಶಿಯನ್ನೊಳಗೊಂಡಿದ್ದು ಕಪ್ಪು ದ್ರವ್ಯ($Dark\ matter$)ದಿಂದ ರೂಪುಗೊಂಡಿವೆ. ನಂತರ ಇವು ಅಸ್ಥಿರತೆಯಿಂದ ಕುಸಿದು, ಸೂಪರ್ನೋವಾ ಆಗದೆ ಕಪ್ಪುಕುಳಿಗಳಾಗಿರಬಹುದು'. ಇತ್ತೀಚಿನ ಸಂಶೋಧನೆಯು ಹೇಳುವಂತೆ 'ಅತಿ ಹೆಚ್ಚಿನ ಕೆಂಪು ಪಲ್ಲಟವನ್ನು($Red\ Shift$) ಹೊಂದಿರುವ ವಿಶ್ವದಂಚಿನ 1,00,000ದಷ್ಟು ಸೌರ ದ್ರವ್ಯರಾಶಿಯ ದ್ರವ್ಯವು ಅತಿ ಹೆಚ್ಚಿನ ಸ್ವಯಂ ಗುರುತ್ವಾಕರ್ಷಣೆಗೊಳಗಾಗಿ ಕುಸಿದು ಕಪ್ಪು ಕುಳಿಯೇರ್ಪಟ್ಟಿದೆ' ಎಂಬುದು.

ಗ್ಯಾಲಾಕ್ಸಿಗಳ ಮಧ್ಯದಲ್ಲಿ ಇರುವ ಅನೇಕ ಕಪ್ಪು ಕುಳಿಗಳು 10 ಶತಕೋಟಿ ವರ್ಷಗಳಿಗೂ ಹಿಂದಿನವೆಂದು ಸಂಶೋಧನೆಯು ಹೇಳುತ್ತದೆ. ಅದರಂತೆ 'ಅನೇಕ ಬೃಹತ್ ಕಪ್ಪು ಕುಳಿಗಳು ವಿಶ್ವವು ರಚನೆಯಾದ ಕೆಲವೇ ಸಮಯದಲ್ಲಿಯೇ ರೂಪಿತವಾಗಿವೆ'.

ಆದಿಸ್ವರೂಪದ ಕಪ್ಪು ಕುಳಿಗಳು ವಿಶ್ವದ ಅನೇಕ ನಿಗೂಢವಾಗಿಯೇ ಉಳಿದಿರುವ ಒಗಟುಗಳನ್ನು ಪರಿಹರಿಸುವ ನಿಟ್ಟಿನಲ್ಲಿವೆ. ಜೇಮ್ಸ್ ವೆಬ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕ ಮತ್ತು ಲೀಸಾ($Laser\ Interferometer\ Space\ antenna - LISA$)ಗಳು ಆದಿಸ್ವರೂಪದ ಕಪ್ಪು ಕುಳಿಗಳ ಅಸ್ಥಿತ್ವವನ್ನು ಸ್ಪಷ್ಟಪಡಿಸಲಿವೆ ಎಂದು ವಿಜ್ಞಾನಿಗಳು ಹೇಳುತ್ತಾರೆ. ಈ ಆದಿಸ್ವರೂಪದ ಕಪ್ಪು ಕುಳಿಗಳು ವಿಲೀನವಾಗೊಂಡಾಗ ಉಂಟಾದ ಗುರುತ್ವ ಅಲೆಗಳ ಸಂಕೇತವನ್ನು ಗುರುತಿಸಿ ಗ್ರಹಿಸುವುದು ಮತ್ತು ಮೊದಲ ನಕ್ಷತ್ರವು ಕಪ್ಪು ಯುಗದ($dark\ age$) ನಂತರ ರೂಪಿತವಾಗಿದ್ದಲ್ಲಿ ಜೇಮ್ಸ್ ವೆಬ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕ ಮತ್ತು ಲೀಸಾ ಅವುಗಳ ಪುರಾವೆಗಳನ್ನು ಕೊಡುವುದೆಂಬ ನಿಟ್ಟಿನಲ್ಲಿ ಸಂಶೋಧನೆಯು ಮುಂದುವರೆಯುತ್ತಿದೆ.

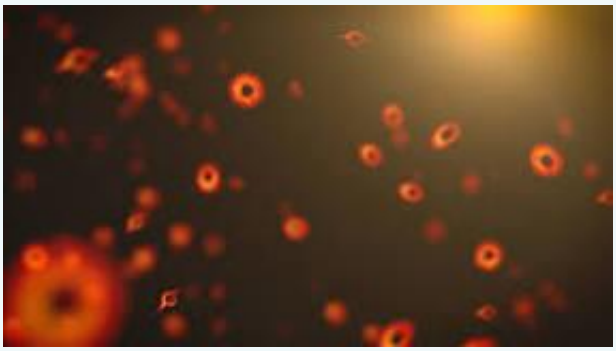
ಆದಿಸ್ವರೂಪದ ಕಪ್ಪು ಕುಳಿಗಳು ರೂಪುಗೊಂಡ ರೀತಿ:

ಲೀಸಾ ವೀಕ್ಷಣೆಗಳು ಹೇಳುವಂತೆ 'ದೊಡ್ಡ ಕಪ್ಪು ಕುಳಿಗಳು ತಮ್ಮ ಅಕ್ಷದ ಮೇಲೆ ತಿರುಗುತ್ತಿರುವುದರಿಂದ ಅವು ವಿದ್ಯುದಾವೇಶವನ್ನು ಉತ್ಪಾದನೆ ಮಾಡುತ್ತಿರುವುದಾಗಿಯೂ' ತಿಳಿದುಬಂದಿದೆ. ಈ ವಿದ್ಯುದಾವೇಶಗೊಂಡ ಕಪ್ಪು ಕುಳಿಗಳು ತಿರುಗುತ್ತಿರುವುದರಿಂದ ಹೆಚ್ಚು ಕಾಲ ಉಳಿಯಬಹುದು ಮತ್ತು ಬಹುಶಃ ಕಪ್ಪು ದ್ರವ್ಯದ ಮೂಲವೂ ಆಗಿರುವ ಸಾಧ್ಯತೆಯಿದೆ ಎಂದು ವಿಜ್ಞಾನಿಗಳ ಅಭಿಮತ. ಮತ್ತೊಂದು ವಿಶ್ಲೇಷಣೆಯ ಪ್ರಕಾರ ಬಿಗ್ ಬ್ಯಾಂಗ್‌ನ ಮೊದಲ$1/10^{30}$ ಸೆಕೆಂಡ್‌ನಲ್ಲಿ ಚಿಕ್ಕ ಚಿಕ್ಕ ಮೊಳಕೆಯಂತಹ ವಿದ್ಯುದಾವೇಶವುಳ್ಳ ಕಪ್ಪು ಕುಳಿಗಳು ರೂಪಿತವಾಗಿದ್ದ ಸಾಧ್ಯತೆ ಇದೆ ಎಂಬುದು. ಅಲ್ಲದೆ ಈ ಕಪ್ಪು ಕುಳಿಗಳನ್ನು ಕಪ್ಪು ದ್ರವ್ಯದ ಮೂಲಕ ವಿವರಿಸಬಹುದೆಂದೂ ಸೈದ್ಧಾಂತಿಕವಾಗಿ ಹೇಳಿದ್ದಾರೆ. ಇವುಗಳ ಗುರುತ್ವದ ಸೆಳೆತದಿಂದಲೇ ಈ ಕಾಣಲಾಗದ ಆದಿಸ್ವರೂಪದ ಚಿಕ್ಕ ಚಿಕ್ಕ ಕಪ್ಪು ಕುಳಿಗಳೇ ಕಪ್ಪು ದ್ರವ್ಯಗಳ ಬೇರುಗಳಂತೆ ಎಂದೂ ಅಭಿಪ್ರಾಯ ಪಡುತ್ತಾರೆ. ಕಪ್ಪು ಕುಳಿಗಳು ಕಪ್ಪು ದ್ರವ್ಯಗಳಲ್ಲದಿದ್ದರೂ, ಕಪ್ಪು ದ್ರವ್ಯವು ಈ ಕಪ್ಪು ಕುಳಿಗಳ ದ್ರವ್ಯವನ್ನೊಳಗೊಂಡಿರುತ್ತವೆ, ಜೊತೆಗೆ ನ್ಯೂಟ್ರಿನೋಗಳಿಂದ ಕೂಡಿ ಕಾಂತೀಯ ಆವೇಶವನ್ನೊಳಗೊಂಡಿರುತ್ತವೆ ಎಂಬುದು ಅನೇಕ ಖಗೋಳ ವಿಶ್ಲೇಷಣೆಯಿಂದ ತಿಳಿದುಬರುತ್ತದೆ.

ಆಗಸದಲ್ಲಿ ಮೊದಲ ನಕ್ಷತ್ರವು ಉದಯವಾಗುವ ಮುಂಚಿತವಾಗಿ ಅಗಾಧವಾದ ಮೋಡದಂತಹ ದ್ರವ್ಯವು ಕುಸಿತ ಕಂಡು ನಕ್ಷತ್ರಗಳ ಪ್ರಭಾವಲಯ ರೂಪುಗೊಂಡಿತು. ಇವು ಅಸ್ಥಿರತೆಯಿಂದ ಕುಸಿದು ಸೂಪರ್ನೋವಾ ಆಗದೆ ಕಪ್ಪು ಕುಳಿಗಳು ರೂಪುಗೊಂಡವು ಎಂಬುದು ಖಗೋಳವಿಜ್ಞಾನಿಗಳ ಸಿದ್ಧಾಂತವಾಗಿದೆ.

2022ರಲ್ಲಿನ ಕಂಪ್ಯೂಟರ್ ಅನುಕರಣೆಯು, ಪ್ರಕ್ಷುಬ್ಧವಾದ ಬೃಹತ್ ಅನಿಲ ರಾಶಿಯಾದ ಆದಿಸ್ವರೂಪದ ಪ್ರಭಾವಲಯ($Primordial\ halos$)ದಿಂದ ಬೃಹತ್ ಕಪ್ಪು ಪುಳಿಗಳು ರೂಪಿತವಾಗಿವೆಯೆಂದು ಹೇಳುತ್ತದೆ. ವಿಶ್ವವು ಉದಯವಾದ ಒಂದು ಶತಕೋಟಿ ವರ್ಷಗಳಲ್ಲಿ, ಒಂದು ಶತಕೋಟಿಯಷ್ಟು ಸೌರದ್ರವ್ಯರಾಶಿಯ ಬೃಹತ್ ಕಪ್ಪು ಕುಳಿಗಳು ರೂಪಿತವಾಗಿತ್ತೆಂದು ಕಂಪ್ಯೂಟರ್ ಅನುಕರಣೆಯ ವರದಿ ತಿಳಿಸುತ್ತದೆ.

ಚಿಕ್ಕ ಕಪ್ಪು ಕುಳಿಗಳು:



ಚಿತ್ರ 5 ಚಿಕ್ಕ ಕಪ್ಪು ಕುಳಿಗಳ ಮಾದರಿ

ಭೂಮಿಯಂತಹ ದ್ರವ್ಯರಾಶಿಯನ್ನೊಳಗೊಂಡ ಅನೇಕ ಚಿಕ್ಕ ಕಪ್ಪು ಕುಳಿಗಳು ಆರಂಭಿಕ ಬ್ರಹ್ಮಾಂಡದ ಅಸ್ತವ್ಯಸ್ತವಾಗಿದ್ದ ಕ್ಷಣಗಳಲ್ಲಿ ರೂಪುಗೊಂಡಿರಬಹುದು ಎಂದು ವಿಜ್ಞಾನಿಗಳು ತಾರ್ಕಿಕವಾಗಿ ಅಥೈ್ಯಸಿದ್ದಾರೆ. ಕಪ್ಪು ಕುಳಿಯಾಗಲು ಕನಿಷ್ಠ ದ್ರವ್ಯರಾಶಿಯ ಅಗತ್ಯವಿದ್ದರೂ ಬ್ರಹ್ಮಾಂಡದ ಸೃಷ್ಟಿಯ ದಿನಗಳಲ್ಲಿ ಪರಿಸ್ಥಿತಿಗಳು ಚಿಕ್ಕ ಹಗುರವಾದ ಕಪ್ಪು ಕುಳಿಗಳನ್ನು ರೂಪಿಸಲು ಅನುಕೂಲವಾಗಿರಬಹುದೆಂದು ಇಲ್ಲಿ ಭಾವಿಸಲಾಗಿದೆ. 1933ರಲ್ಲಿ ಖಗೋಳವಿಜ್ಞಾನಿ ಫ್ರಿಟ್ಜ್ ಜ್ವಿಕಿ ಪ್ರಸ್ತಾಪಿಸಿದ ಸಿದ್ಧಾಂತದ ಪ್ರಕಾರ ವಿಶ್ವದ ದ್ರವ್ಯರಾಶಿಯ ಪ್ರತಿಶತ 30 ಭಾಗವಿರುವ 'ಕಪ್ಪು ದ್ರವ್ಯ'ವು ಗ್ಯಾಲಕ್ಸಿಗಳಲ್ಲಿ ಕಂಡುಬರುವ ಗುರುತ್ವಾಕರ್ಷಣೆಯ ಪರಿಣಾಮವನ್ನು ವಿವರಿಸುತ್ತವೆ. ಇದಲ್ಲದೆ ಮತ್ತೂ ಅನೇಕ ಕಾರಣಗಳಿಂದಾಗಿ ಚಿಕ್ಕ ಚಿಕ್ಕ ಕಪ್ಪು ಕುಳಿಗಳು ಕಪ್ಪು ದ್ರವ್ಯದಿಂದ ಆಗಿರಬಹುದೆಂಬ ಸಿದ್ಧಾಂತವನ್ನು ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಮಂಡಿಸಿದ್ದಾರೆ. ಈ ಚಿಕ್ಕ ಆದಿಸ್ವರೂಪದ ಕಪ್ಪು ಕುಳಿಗಳು ಯಾವುದೇ ಗಾತ್ರವನ್ನು ಹೊಂದಿ ಗ್ಯಾಲಕ್ಸಿಗಳ ರಚನೆಗೆ ತಮ್ಮ ಕೊಡುಗೆ ನೀಡಿರಬಹುದು ಎನ್ನುತ್ತಾರೆ (ಚಿತ್ರ 5).

ಆದಿ ಸ್ವರೂಪದ ಕಪ್ಪು ಕುಳಿಗಳ ಸೃಷ್ಟಿಯು ಮೊದಲ ನಕ್ಷತ್ರಗಳಿಗೆ ಮುಂಚಿತವಾಗಿದ್ದು ಅವು ನಕ್ಷತ್ರಗಳಿಂದ ರೂಪಿವಾಗಿರುವ ಕಪ್ಪು ಕುಳಿಗಳ ಸಮೂಹಕ್ಕೆ ಸೀಮಿತವಾಗಿಲ್ಲ. 1971ರಲ್ಲಿ ಸ್ಟೀಫನ್ ಹಾಕಿಂಗ್ ಟಿ ಸಿ ದೂರದರ್ಶಕದಿಂದ ಕಂಡುಹಿಡಿದ ಅತಿದೊಡ್ಡ ಆದಿ ಸ್ವರೂಪದ ಕಪ್ಪು ಕುಳಿಗಳು ಇನ್ನೂ ಸಂಶೋಧನಾ ಹಂತದಲ್ಲಿವೆ.

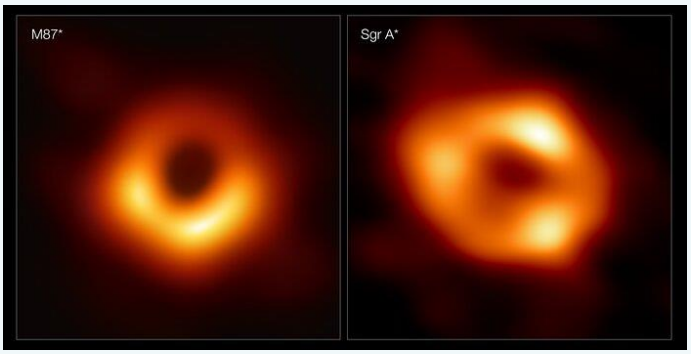
ಭೂಮಿಯಂತಹ ದ್ರವ್ಯರಾಶಿಯನ್ನು ಒಳಗೊಂಡಂತೆ ಚಿಕ್ಕ ಆದಿ ಕಪ್ಪು ಕುಳಿಗಳು ಮಹಾಸ್ಫೋಟದ ನಂತರ ವಿಶ್ವದ ಅಸ್ತವ್ಯಸ್ತ ಆರಂಭಿಕ ಹಂತದ ಕ್ಷಣಗಳಲ್ಲಿ ರೂಪುಗೊಂಡಿರಬಹುದೆಂದು ಖಗೋಳವಿಜ್ಞಾನಿಗಳ ತರ್ಕವಾಗಿದೆ. ಬ್ರಹ್ಮಾಂಡವು ರಚನೆಯಾಗುತ್ತಿದ್ದಂತೆಯೇ ಅದು ಬಾಹ್ಯಾಕಾಶದಲ್ಲಿ ಬೆಳಕಿನ ವೇಗದಲ್ಲೇ ವಿಸ್ತರಿಸಿದೆ. ಈ ವಿಶೇಷ ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ, ಇದರ ಸುತ್ತಮುತ್ತಲಿನ ದಟ್ಟವಾದ ಪ್ರದೇಶಗಳು ಕುಸಿದು ಕಡಿಮೆ ದ್ರವ್ಯರಾಶಿಯ ಆದಿಸ್ವರೂಪದ ಕಪ್ಪು ಕುಳಿಗಳು ರೂಪಿತವಾಗಿರಬಹುದೆಂದು ಕೆಲವು ಖಗೋಳವಿಜ್ಞಾನಿಗಳ ತರ್ಕವಾಗಿದೆ. ಈ ಬಗೆಯ ಚಿಕ್ಕ ಕಪ್ಪು ಕುಳಿಗಳು ನಕ್ಷತ್ರಪುಂಜದಲ್ಲಿ ಸುಪ್ತವಾಗಿದ್ದು ಅದರ ದ್ರವ್ಯರಾಶಿಯು ಸ್ಪೇಸ್–ಟೈಮ್‌ನ ಚೌಕಟ್ಟನ್ನು ಟ್ರ್ಯಾಂಪೊಲಿನ್‌ನಂತೆ ವಿರೂಪಗೊಳಿಸುತ್ತವೆ.

ಈ ಚಿಕ್ಕ ಕಪ್ಪು ಕುಳಿಗಳು ತಮ್ಮ ಈವೆಂಟ್ ಹೊರೈಜನ್‌ನಲ್ಲಿ ಇಳಿಜಾರು ಓಟದಂತೆ ಒಳಪ್ರದೇಶವನ್ನು ಪ್ರವೇಶಿಸಿ ಏಕತ್ವ ($singularity$)ದಲ್ಲಿ ಲೀನವಾಗಿವೆ. ಈ ಚಿಕ್ಕ ಕಪ್ಪು ಕುಳಿಗಳು ಐನ್‌ಸ್ಟಿನ್ನರ ಸಾಪೇಕ್ಷ ಸಿದ್ಧಾಂತ ಮತ್ತು ಕ್ವಾಂಟಮ್ ಮೆಕಾನಿಕ್ಸ್ ಲಾ ಅನ್ವಯದಂತೆ ಇವೆ. ಇವುಗಳು

ಕಾಲ ಕಳೆದಂತೆ ಹಾಕಿನ್ಸ್ ವಿಕಿರಣಗಳನ್ನು ಹೊರಹಾಕಿ ತಮ್ಮ ಗಾತ್ರದಲ್ಲಿ ಕುಗ್ಗುತ್ತಾ ಬಾಷ್ಪೀಕರಣದಿಂದ ಕಣ್ಮರೆಯಾಗಿ ಆಗಸದಲ್ಲಿ ಅನೇಕ ಕಣಗಳಾಗಿರುವ ಸಂಭವವಿದೆ. ಅವುಗಳು ಕಪ್ಪು ದ್ರವ್ಯವೂ ಆಗಿರಬಹುದು ಎನ್ನುತ್ತಾರೆ ಖಗೋಳ ವಿಜ್ಞಾನಿಗಳು.

ಕಪ್ಪು ಕುಳಿಯ ಪ್ರತಿಬಿಂಬ:

ನಮಗೆ ತಿಳಿದಿರುವಂತೆ ಕಪ್ಪು ಕುಳಿಯ ಆಕಾರವು ಅಗೋಚರವಾಗಿದ್ದು ಅದರಿಂದ ಅನೇಕ ವಿಕಿರಣಗಳು ಹೊರಹೊಮ್ಮುತ್ತಿವೆ. ಆದರೆ ಇದುವರೆಗೆ ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಎರಡು ಬೃಹತ್ ಕಪ್ಪು ಕುಳಿಗಳ ಚಿತ್ರಣವನ್ನು ಪಡೆಯುವುದರಲ್ಲಿ ಸಫಲರಾಗಿದ್ದಾರೆ. ಅವುಗಳೆಂದರೆ ಮೆಸಿಯರ್87* ಅಥವಾ $M87^*$ ಮತ್ತು ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿರುವ ಸೆಗಿಟೇರಿಯಸ್ಎ* ಅಥವಾ Sgr^*. 2018ರಲ್ಲಿ ಖಗೋಳವಿಜ್ಞಾನಿಗಳಿಂದ, 55 ದಶಲಕ್ಷ ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿರುವ ಮೆಸಿಯರ್87 ($Messier\ 87$) ಎಂಬ ಬೃಹತ್ ಅಂಡಾಕಾರದ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ $M87^*$ ಎಂಬ ಕಪ್ಪು ಕುಳಿಯ ಚಿತ್ರಣವನ್ನು 'ಈವೆಂಟ್ ಹೊರೈಜನ್ ದೂರದರ್ಶಕ'ದಲ್ಲಿ

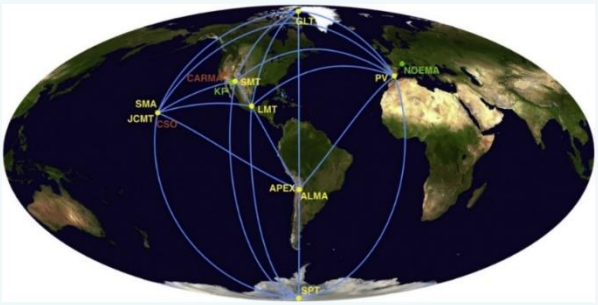


ಚಿತ್ರ 6 ಮೆಸಿಯರ್87* ಮತ್ತು ಸಗಿಟೇರಿಯಸ್ಎ*ಗಳ ಪ್ರತಿಬಿಂಬ

ಸೆರೆಹಿಡಿಯಲಾಗಿದೆ. ಈ ದೂರದರ್ಶಕವು ವಿಶೇಷವಾಗಿದ್ದು ಪ್ರಪಂಚದಾದ್ಯಂತ ಜಾಲಬಂಧವನ್ನು ಹೊಂದಿದ್ದು, ಸುಮಾರು 8ಕ್ಕೂ ಹೆಚ್ಚು ರೇಡಿಯೋ ದೂರದರ್ಶಕವನ್ನು ಹೊಂದಿದೆ.

ಚಿತ್ರದ ಎಡಗಡೆಯಲ್ಲಿ ಕಾಣುತ್ತಿರುವುದು $M87$ಎಂಬ ಕಪ್ಪು ಕುಳಿ ಮತ್ತು ಬಲಗಡೆಯದು ಸಗಿಟೇರಿಯಸ್‌ಎ* ರೇಡಿಯೋ ಅಲೆಗಳ ಚಿತ್ರಣ (ಚಿತ್ರ 6). ಒಳ ಭಾಗದ ಚಿತ್ರಣದ ಬೆಳಕು ಕಪ್ಪು ಕುಳಿಯ ಹಿಂಭಾಗದ್ದು. ಪ್ರಕಾಶಮಾನವಾದ ಕಿತ್ತಲೆ ಬಣ್ಣವು ಕಪ್ಪು ಕುಳಿಯ ಸುತ್ತಲೂ ಇರುವ ನಕ್ಷತ್ರಗಳದ್ದು. ಈ ಕಪ್ಪು ಕುಳಿಗಳ ಚಿತ್ರಣವು ಬಾಹ್ಯಾಕಾಶ ತಂತ್ರಜ್ಞಾನದ ಅದ್ಭುತವೇ ಸರಿ. ಇದು ತನ್ನ ಅಕ್ಷದ ಮೇಲೆ ವೇಗವಾಗಿ ತಿರುಗುತ್ತಿರುವುದರಿಂದ ಇದರ ಚಿತ್ರಣವನ್ನು ತೆಗೆಯುವುದು ಸವಾಲಿನ ಕೆಲಸವೇ ಆಗಿದೆ.

ಚಿತ್ರದ ಬಲಭಾಗವು ಸಗಿಟೇರಿಯಸ್‌ಎ* ಅಥವಾ Sgr^* ಕಪ್ಪು ಕುಳಿಯ ರೇಡಿಯೋ ಅಲೆಗಳ ಚಿತ್ರಣ. ಇದರ ಚಿತ್ರಣವನ್ನೂ 'ಈವೆಂಟ್ ಹೊರೈಜನ್' ದೂರದರ್ಶಕ(ಚಿತ್ರ 7)ದಲ್ಲಿ ತೆಗೆಯಲಾಗಿದೆ. ಇದನ್ನು 2022ರ ಮೇನಲ್ಲಿ ಪ್ರಟಪಡಿಸಿದರು. ಇದು ಸುರುಳಿಯಾಕಾರದ ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯ ಸಗಿಟೇರಿಯಸ್ ನಕ್ಷತ್ರಪುಂಜ (ಧನುರಾಶಿ)ದಲ್ಲಿದ್ದು, ಭೂಮಿಯಿಂದ 27000 ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿದೆ. 40 ಲಕ್ಷ ಸೌರದ್ರವ್ಯರಾಶಿಯನ್ನು ಹೊಂದಿರುವ ಸಗಿಟೇರಿಯಸ್‌ಎ* ಕಪ್ಪು ಕುಳಿಯು ಈವೆಂಟ್ ಹೊರೈಜನ್ ಭಾಗವೂ ಸೇರಿ 26 ದಶ ಲಕ್ಷ ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದೆ.



ಚಿತ್ರ 7 ಈವೆಂಟ್ ಹೊರೈಜನ್ ರೇಡಿಯೋ ದೂರದರ್ಶಕದ ಜಾಲಬಂಧ

ವೇಳಾ ಯಂತ್ರ (*TIME MACHINE*): ಗ್ಯಾಲಾಕ್ಸಿಗಳ ಮಧ್ಯದಲ್ಲಿ ಇರುವ ದೈತ್ಯ ಕಪ್ಪು ಕುಳಿಗಳು 10 ಶತಕೋಟಿ ವರ್ಷಗಳಿಗೂ ಮುಂಚಿತವಾಗಿ ಹೇಗೆ ರೂಪಿತವಾದವು ಎಂಬುದರ ಬಗ್ಗೆ ಖಗೋಳ ವಿಜ್ಞಾನಿಗಳ ಸಂಶೋಧನೆ ಇನ್ನೂ ನಡೆಯುತ್ತಿದೆ, ಅವು ನಕ್ಷತ್ರಗಳಿಂದ ರೂಪಿತವಾಗಿಲ್ಲವೆಂದು ನಿರ್ಧಾರಿಸಿದ್ದಾರೆ. ನಾವು 10 ಶತಕೋಟಿ ವರ್ಷ ಹಿಂದೆ ಹೋಗಲು ಸಾಧ್ಯವಿಲ್ಲದಿದ್ದರೂ, 10 ಶತಕೋಟಿ ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದ ಬೃಹತ್ ದೈತ್ಯ ಗ್ಯಾಲಾಕ್ಸಿಗಳಿಂದ ಬರುವ, 10 ಶತಕೋಟಿ ಜ್ಯೋತಿರ್ವರ್ಷದ ರೇಡಿಯೋ ಅಲೆಗಳನ್ನು ಪರೀಕ್ಷಿಸಬಹುದು. ಇವು ಆ ಗ್ಯಾಲಾಕ್ಸಿಗಳಿಂದ 10 ಶತಕೋಟಿ ವರ್ಷಗಳ ಹಿಂದೆ ಬಂದಿರುತ್ತವೆಯಷ್ಟೆ. ಈ ರೇಡಿಯೋ ಅಲೆಗಳನ್ನು ಅಧ್ಯಯನ ಮಾಡುವುದರಿಂದ ದೂರದ ದೈತ್ಯ ಗ್ಯಾಲಾಕ್ಸಿಗಳು ಎಷ್ಟು ಬೃಹತ್ತಾಗಿವೆ ಎಂದು ಮತ್ತು ಅದರ ಮಧ್ಯದಲ್ಲಿ ಅಡಗಿರುವ ಕಪ್ಪು ಕುಳಿಯ ಬಗ್ಗೆ ಮಾಹಿತಿಯನ್ನು ತಿಳಿಯಬಹುದಾಗಿದೆ ಎಂಬುದು ವಿಜ್ಞಾನಿಗಳ ಲೆಕ್ಕಾಚಾರ. ಉದಾಹರಣೆಗೆ ಪೂಣೆಯ ಬಳಿ ಇರುವ ಜಯಂಟ್ ಮೀಟರ್‌ವೇವ್

ಚಿತ್ರ 8 ಜಯಂಟ್ ಮೀಟರ್‌ವೇವ್ ರೇಡಿಯೋ ದೂರದರ್ಶಕ

ರೇಡಿಯೋ ದೂರದರ್ಶಕ(ಜಿ ಎಮ್ ಆರ್ ಟಿ)ದಿಂದ ವಿಶ್ವವು 9 ಶತಕೋಟಿ ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದ ಅತಿ ದೊಡ್ಡ ರೇಡಿಯೋ ಗ್ಯಾಲಾಕ್ಸಿಯಿಂದ ಬಂದ ರೇಡಿಯೋ ಸಂಕೇತವನ್ನು ನ್ಯಾಷನಲ್ ಸೆಂಟರ್ ಫಾರ್ ರೇಡಿಯೋ ಅಸ್ಟ್ರೋಫಿಸಿಕ್ಸ್ ತಂಡದವರು ಅಧ್ಯಯನ ಮಾಡಿದ್ದಾರೆ (ಚಿತ 8).

ವಿಶ್ವದ ಹುಟ್ಟು ಮತ್ತು ಬೆಳಗು:

ವಿಶ್ವವು ಈಗಿರುವಂತೆ ಬೆಳೆಯಬೇಕಾದರೆ ಅನೇಕ ಹಂತಗಳನ್ನು ಹೊಂದಿದೆ. ಮಹಾಸ್ಫೋಟವಾದ ಸುಮಾರು 3.8ರಿಂದ ಒಂದು ಶತಕೋಟಿ ವರ್ಷಗಳ ತನಕವೂ ವಿಶ್ವವು ಕತ್ತಲೆಯಿಂದ ಕೂಡಿತ್ತು. ಬೆಳಕಿನ ಯಾವ ಆಗರವೂ ಇಲ್ಲದೆ ಕತ್ತಲೆಯಿಂದಲೇ ಕೂಡಿ ಕಪ್ಪು ಯುಗವೆಂದೇ ಕರೆಯಲಾಯಿತು. ಆ ವೇಳೆಯಲ್ಲಿ ವಿಶ್ವವು ಅತಿ ಉಷ್ಣಾಂಶದಿಂದ ಕೂಡಿದ ಸಾಂದ್ರವಾದ ಅಯನೀಕೃತ ಪ್ಲಾಸ್ಮಾದಿಂದ ಕೂಡಿ, ಕ್ರಮೇಣ ಉಷ್ಣತೆಯು ಕಡಿಮೆಯಾಗುತ್ತಾ ಬೆಳಕು, ಪ್ರೋಟಾನ್, ಎಲಕ್ಟ್ರಾನ್‌ಗಳಿಂದ ಕೂಡಿ ನಂತರ ಜಲಜನಕದ ಆಟಂಗಳು ಉಂಟಾದವು. ಅದರಿಂದಲೇ ಮೊದಲ ನಕ್ಷತ್ರ ಮತ್ತು ಗ್ಯಾಲಾಕ್ಸಿ ರೂಪುಗೊಂಡು ಅತಿನೇರಳೆ ಬೆಳಕು ಬಿಡುಗಡೆಯಾಗಿ ನಕ್ಷತ್ರದ ಸುತ್ತಮುತ್ತಲ

ಇರುವ ಜಲಜನಕವು ಅಯನೀಕೃತಗೊಂಡಿತು. ಇದನ್ನೇ 'ವಿಶ್ವದ ಬೆಳಗು' ಎನ್ನಲಾಯಿತು. ಕಪ್ಪು ಯುಗವು ಸುಮಾರು 200 ದಶಲಕ್ಷ ವರ್ಷಗಳ ನಂತರ ವಿಶ್ವವನ್ನು ಮುಸುಕಿದ್ದ ಪೊರೆ ಕಳೆದು ವಿಶ್ವದ ಬೆಳಗು ಆಯಿತು.

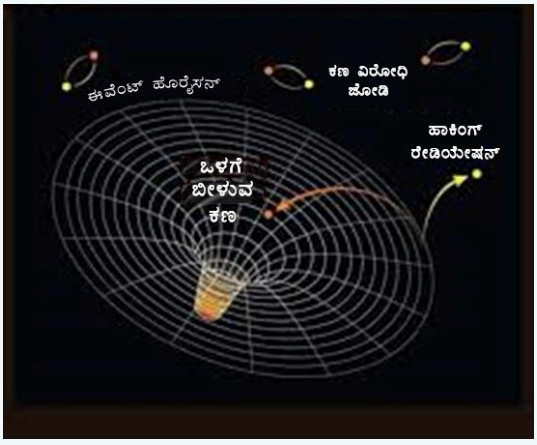
ಚಿತ್ರ 9 ವಿಶ್ವದ ಬೆಳಗಿನ ನಂತರ ಜೇಮ್ಸ್ ವೆಬ್ ಗುರುತಿಸಿದ ಐದು ನಕ್ಷತ್ರ ಸಮೂಹಗಳು

ಜೇಮ್ಸ್ ವೆಬ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕದಿಂದ 'ವಿಶ್ವದ ಬೆಳಗು' ಹೇಗೆ ಉಂಟಾಯಿತು ಎಂಬುದನ್ನು ಗಮನಿಸಲಾಗಿದೆ (ಚಿತ್ರ 9). ಈ ದೂರದರ್ಶಕವು ವಿಶ್ವವು ಮಹಾಸ್ಫೋಟವಾದ ಕೇವಲ 46 ಕೋಟಿ ವರ್ಷಗಳ ನಂತರ ರೂಪುಗೊಂಡ ಅತಿಯಾದ ಸಾಂದ್ರತೆಯುಳ್ಳ ಐದು ನಕ್ಷತ್ರ ಸಮೂಹವನ್ನು ಗುರುತಿಸಿದೆ. ಇದನ್ನು 'ವಿಶ್ವ ರತ್ನ'ಗಳೆಂದೇ ಕರೆಯುವರು. ಇವುಗಳಲ್ಲಿ ಲಕ್ಷಾಂತರ ನಕ್ಷತ್ರಗಳು ಗುರುತ್ವಾಕರ್ಷಣೆಗೊಳಗಾಗಿ ಒಂದು ಗುಂಪುಗಳಲ್ಲಿ ಸೇರಿ ಗ್ಯಾಲಾಕ್ಸಿಗಳಾಗಿ ರೂಪುಗೊಂಡಿವೆ. ಇವುಗಳ ಅಧ್ಯಯನ ಮಾಡುವುದರಿಂದ ವಿಶ್ವದ ಆರಂಭದ ಅನೇಕ ರಹಸ್ಯವನ್ನು ತಿಳಿಯಬಹುದೆಂದು ಅದರ ಅನ್ವೇಷಣೆಯಲ್ಲಿ ತೊಡಗಿದ್ದಾರೆ.

ಇದಕ್ಕೆ ಸಹಾಯವಾಗುವಂತೆ ಅತಿ ದೂರದಲ್ಲಿರುವ ಪ್ರಕಾಶಮಾನವಾದ 67 ಕ್ವೆಸಾರ್‌ಗಳ ಬೆಳಕಿನ ಸಹಾಯದಿಂದ ವಿಶ್ವದಲ್ಲಿ ಬೆಳಗುತ್ತಿದ್ದ ಮೊದಲ ನಕ್ಷತ್ರವು ಮಿನುಗುವುದನ್ನು ಕಂಡುಹಿಡಿದಿದ್ದಾರೆ. ಅದು ಮಹಾಸ್ಫೋವಾದ 1.1 ಶತಕೋಟಿ ವರ್ಷಗಳ ಹಿಂದೆ ಎಂದು ತಿಳಿದು ಬಂದಿದೆ. ಈ ಕ್ವೆಸಾರ್‌ಗಳು ಬೃಹತ್ ಕಪ್ಪು ಪುಳಿಗಳಿಂದ ಶಕ್ತಿಯನ್ನು ಪಡೆದು ಪ್ರಕಾಶಮಾನವಾಗಿರುತ್ತವೆ.

ಮುಂದಿನ ವರ್ಷಗಳಲ್ಲಿ ನಾಸಾದ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕವಾದ 'ನ್ಯಾನ್ಸಿ ಗ್ರೇಸ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕ'ವು ವಿಶ್ವದ ಗ್ಯಾಲಾಕ್ಸಿಗಳನ್ನು ಶೋಧಿಸಿ ವಿಶ್ವದ ರಹಸ್ಯವನ್ನು ಮತ್ತಷ್ಟು ತೆರೆದಿಡುವ ದಿಸೆಯಲ್ಲಿ ಹೊರಬರುತ್ತಿದೆ. ಅಜ್ಞಾತವಾಗಿರುವ ಪ್ರತಿಶತ 95 ಭಾಗವು ಕಪ್ಪು ದ್ರವ್ಯ ಮತ್ತು ಕಪ್ಪು ಶಕ್ತಿಯಿಂದ ಕೂಡಿದ್ದು, ಬಾಹ್ಯಾಕಾಶದ ಗ್ಯಾಲಾಕ್ಸಿ ಮತ್ತಿತರ ಆಕಾಶ ಕಾಯಗಳು ಕೇವಲ ಪ್ರತಿಶತ 5 ಭಾಗದಿಂದ ಕೂಡಿದೆಯೆಂದು ಸಂಶೋಧನೆಯಿಂದ ತಿಳಿದುಬಂದಿದೆ. ವಿಶ್ವದ ವಿಕಾಸದಲ್ಲಿ ಮುಖ್ಯ ಪಾತ್ರ ವಹಿಸುತ್ತಿರುವ ಅಜ್ಞಾತವಾದ ಕಪ್ಪು ದ್ರವ್ಯ ಮತ್ತು ಕಪ್ಪು ಶಕ್ತಿಯ ಸಂಶೋಧನೆಗೆ ಈ ದೂರದರ್ಶಕವು ಸಹಾಯವಾಗುತ್ತದೆಯೆಂದು ಭಾವಿಸೋಣ.

ಕಪ್ಪುಕುಳಿಗಳ ಬಾಷ್ಪೀಕರಣ–ಹಾಕಿಂಗ್ ರೇಡಿಯೇಶನ್:



ಚಿತ್ರ 10 'ಹಾಕಿಂಗ್ ರೇಡಿಯೇಷನ್ಸ್

ವಿಶ್ವದಲ್ಲಿ ಅತಿ ಹೆಚ್ಚು ಸಾಂದ್ರತೆಯ ಆಕಾಶಕಾಯವೆಂದರೆ ಕಪ್ಪು ಕುಳಿಗಳು. ಕಪ್ಪುಕುಳಿಗಳಿರುವೆಡೆ ಸ್ಪೇಸ್–ಟೈಮ್ ತೀವ್ರವಾಗಿ ಬಾಗಿರುತ್ತದೆ. ಅಲ್ಲಿಂದ ಯಾವ ಸಂಕೇತವೇ ಆಗಲಿ, ಬೆಳಕು ಕೂಡಾ ಹೊರಬರಲು ಸಾಧ್ಯವಿಲ್ಲ. ಆದರೆ 1974ರಲ್ಲಿ ಭೌತವಿಜ್ಞಾನಿ ಸ್ಟೀಫನ್ ಹಾಕಿಂಗ್ ಅವರು ಕಪ್ಪುಕುಳಿಗಳು ಬಾಹ್ಯಾಕಾಶದಲ್ಲಿ ಶಾಶ್ವತವಾಗಿರುವುದಿಲ್ಲ, ಅವು ವಿಕಿರಣವನ್ನು ಹೊರಹೊಮ್ಮುತ್ತಾ ಆವಿಯಾಗಿ ಅಂತಿಮವಾಗಿ ಇಲ್ಲವಾಗುತ್ತವೆ ಎಂದು ಕ್ವಾಂಟಮ್ ಸಿದ್ಧಾಂತದ ಮೂಲಕ ವಿವರಿಸಿದ್ದಾರೆ. 'ಕಪ್ಪು ಕುಳಿಯ ಈವೆಂಟ್ ಹೊರೈಸನ್ ಬಳಿ ಕ್ವಾಂಟಮ್ ಏರಿಳಿತಗಳು ಕಣ–ವಿರೋಧಿ ಜೋಡಿ $(particle - antiparticle\ pairs)$ಗಳನ್ನು ಸೃಷ್ಟಿಸುತ್ತವೆ' ಎಂಬ ಸಿದ್ಧಾಂತವನ್ನು ಪ್ರತಿಪಾದಿಸುವ ಮೂಲಕ ಕಪ್ಪು ಕುಳಿಗಳು ಆವಿಯಾಗುತ್ತವೆ ಎಂದು ಪ್ರಸ್ತಾಪಿಸಿದರು. ಆ ಕಣ–ವಿರೋಧಿ ಜೋಡಿಗಳಲ್ಲಿ ಒಂದು ಕಣವು ಕಪ್ಪು ಕುಳಿಯೊಳಗೆ ಬಿದ್ದರೆ ಮತ್ತೊಂದು ತಪ್ಪಿಸಿಕೊಂಡು ಶಕ್ತಿಯನ್ನು ಹೊರ ತಳ್ಳುತ್ತದೆ. ಇದರಿಂದಾಗಿ ಕಪ್ಪು ಕುಳಿ ಕಾಲಾನಂತರದಲ್ಲಿ ದ್ರವ್ಯರಾಶಿ ಮತ್ತು ಶಕ್ತಿಯನ್ನು ಕಳೆದುಕೊಳ್ಳುತ್ತಾ ಆವಿಯಾಗಿ ವಿಶ್ವದಲ್ಲಿ ಲೀನವಾಗುತ್ತದೆ. ಹೀಗೆ ತಪ್ಪಿಸಿಕೊಂಡು ಆವಿಯಾಗುವ ಶಕ್ತಿಯೇ ವಿಕಿರಣ ರೂಪದ 'ಹಾಕಿಂಗ್ ರೇಡಿಯೇಶನ್ಸ್ (ಚಿತ್ರ 10). ಈ ಸಿದ್ಧಾಂತವನ್ನು ವಿಜ್ಞಾನಿಗಳು ಮುಕ್ತವಾಗಿ ಸ್ವೀಕರಿಸಿರಲಿಲ್ಲ. 1998ರ ಲೆಕ್ಕಾಚಾರದ ಪ್ರಕಾರ,

ಪ್ರಾಚೀನ ವಿಶ್ವದಲ್ಲಿ ದೈತ್ಯ ನಕ್ಷತ್ರಗಳ ಗುರುತ್ವ ಶಕ್ತಿಯ ಕುಸಿತದಿಂದ ರೂಪಿತಗೊಂಡ ಸೌರ ಕಪ್ಪು ಪುಳಿಗಳು ಹಾಕಿಂಗ್ ರೇಡಿಯೇಶನ್‌ಅನ್ನು ಹೊರಹೊಮ್ಮುತ್ತಾ 10^{64} ವರ್ಷಗಳಲ್ಲಿ ಆವಿಯಾಗಿ ಹೋಗುತ್ತವೆ. ಈ ಕಾಲವು ವಿಶ್ವವು ರಚನೆಯಾದ ಕಾಲಕ್ಕಿಂತ ಹೆಚ್ಚಾಗಿದೆ. 2019ರಲ್ಲಿ ಕೆಲವು ಸಂಶೋಧಕರು ಹಾಕಿಂಗ್ ರೇಡಿಯೇಶನ್ಸ್ ಕಪ್ಪು ಕುಳಿಯ ಈವೆಂಟ್ ಹೊರೈಸನ್‌ಗೆ ಬಿದ್ದ ವಸ್ತುವಿನ ಕೆಲವು ಮಾಹಿತಿಯನ್ನು ತಿಳಿಯಬಹುದೆನ್ನುತ್ತಾರೆ.

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ಕೃಷ್ಣ ರಂಧ್ರೆಯರು

ಕೃಷ್ಣ ರಂಧ್ರೆಯರು ವಿಶ್ವದ ನಿಗೂಢ ಕನ್ಯೆಯರು
ತಾರಾ ಪುಂಜದಲ್ಲಡಗಿಹರವರು ll

ಅವರಿಗಿಹುದು ಗರಿಷ್ಠ ಗುರುತ್ವ
ತುದಿಯಲ್ಲಿಹುದು ಘಟನಾ ಬಾನಂಚು
ಯಾವುದೂ ಹೊರಹೋಗಲಾಗದು ಬಾನಂಚಿನಾಚೆ
ವಿದ್ಯುತ್‌ಕಾಂತೀಯ ಅಲೆಗಳೊಂದಿಗಿನ ಬೆಳಕೂ ಸ್ತಬ್ಧll

ಇದರ ಸಂಶೋಧನೆಗೆ ಅಡಿಪಾಯ ಹಾಕಿದರು
ಭಾರತ ಸಂಜಾತ ಸುಬ್ರಮ್ಹಣ್ಯ ಚಂದ್ರಶೇಖರರು
ಕನಿಷ್ಠ ಮೂರ್‌ನಾಲ್ಕು ಸೌರ ರಾಶಿಯ ತಾರೆಯರು
ಜೀವನದಂತ್ಯದಲಿ ಕೃಷ್ಣರಂಧ್ರೆಯರಾಗಲು ಸಿದ್ಧರಾಗುವರುll

ಮೊದಲವರು ಆಸ್ಫೋಟಿಸಿ ಘರ್ಜಿಸುವರು
ತಮ್ಮ ಗುರುತ್ವವನು ಎದುರಿಸಲವರು
ಅಸಹಾಯಕರಾಗವರು ಅವನತಿ ಹೊಂದವರು
ಕೃಷ್ಣ ರಂಧ್ರೆಯರಾಗಿ ಏಕತ್ವವನು ಕಾಣುವರು ll

ಕೆಲವಲ್ಲವರು ಸಜಾತಿ ಭಕ್ಷಿಣಿಯರು
ಸಮೀಪ ಬಂದ ತಾರೆಯರನೇ ಭಕ್ಷಿಸುವರವರು
ತಮ್ಮ ಶಾಖವನವರು ತಾವೇ ಸವಿಯುವರು
ಈ ಅದೃಶ್ಯ ಕನ್ಯೆಯರುll

ತಾರಾಪುಂಜ ಕೇಂದ್ರದಲಿಹರು ಬೃಹತ್ ಕೃಷ್ಣ ರಂಧ್ರೆಯರು
ಹತ್ತು ಶತಕೋಟಿ ವರುಷಗಳಿಗೂ
ಹಿಂದಿನವರೆಂದು ವಿಜ್ಞಾನಿಗಳಲಿ ಜಿಜ್ಞಾಸೆ
ಹಾಗಾದರವರು ಯಕ್ಷಿಣಿಯರೇ ll

ವಿಶ್ವದ ಅನ್ವೇಷಣೆಗೆ ಕೈಗನ್ನಡಿ
ಬಾನಲ್ಲಿ ದೂರದರ್ಶಕ ಜೇಮ್ಸ್ ವೆಬ್
ಸೇರುವಳು ಕೆಲವೇಳೆಯಲಿ ನ್ಯಾನ್ಸಿ ಗ್ರೇಸ್
ಇವರೆಲ್ಲ ಅನ್ವೇಷಕರು ಮತ್ತಷ್ಟು ಕೃಷ್ಣರಂಧ್ರೆಯರ ಕಾಳಜಿಗೆll

– ಡಾ. ಶಾರದಾ ನಾಗಭೂಷಣ

Why is it hard for humans to travel to Mars

H.D. Ananda

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Master Control Facility, Hassan, ISRO

Why is it so hard for humans to travel to Mars, and why has no one done It?

Traveling to Mars presents enormous difficulties due to its immense distance, varies from 55 to 401 million kms, the closest and farthest points respectively. A Spacecraft using today's chemical propulsion engines, travelling at a speed of about 20,000 kms/hour (5.56 kms/sec), will take a minimum of 8 to 9 months to reach Mars. (Flying to moon takes ~3 days). But even though we travel there, getting back safely is the hard part.

The Earth and Mars, orbit the Sun at different speeds and paths (1 Mars year=687 Earth days). We have to wait until both Earth and Mars return to their closest relative positions, in their orbits. This takes about 27 months (2 years and 3 months). So, a trip to Mars and getting back can only happen once every, roughly, 27 months.

When Mars is on the opposite side of the Sun from Earth, it creates a favourable alignment in their respective orbits, for an energy efficient return trip. This requires an approximate, Stay time of 9 months on Mars. Further, a return trip to get back home will be 8 to 9 months.

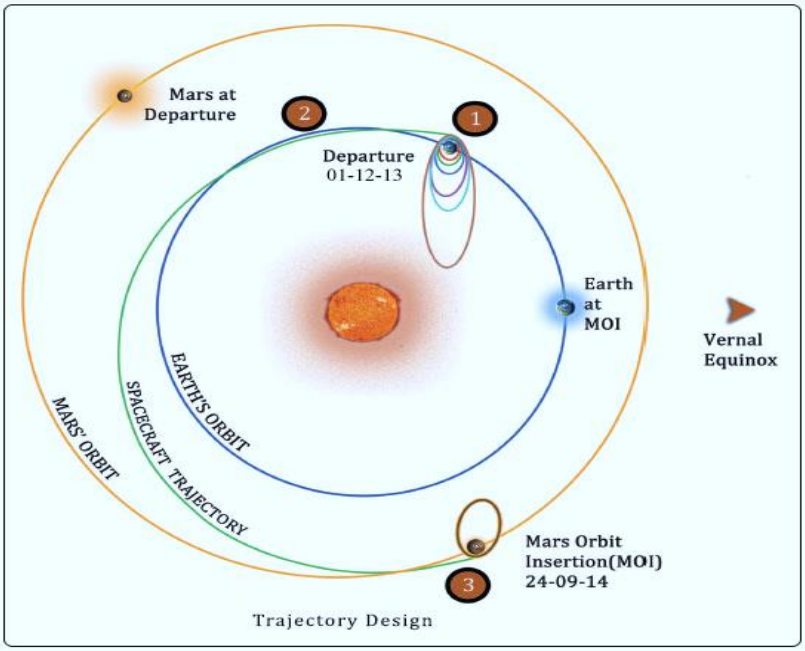
Thus, the total time period for a "Mars Mission" will be almost 2.5 years. "That's A Long Time In Deep Space," which may be boring

Some voyagers say, if we were to ever get things like Nuclear or Plasma engines may be we could get there in 1 to 2 months and reduce travel time but we would still need to wait for the planets to be in the right positions before leaving or coming back.

The difficulties and challenges are immense - Exposure to harmful cosmic radiation, where in shielding would be essential but it would be heavy and costly. Mars atmosphere is very thin making spacecraft's landing and take off very difficult. The thin atmosphere and the planet's gravity also pose challenges for slowing down while spacecraft entering the Martian atmosphere

In addition, we need enough food, water, fuel and a place for the astronauts to hang on while they do their science and exploration experiments. Meaning it's going to take time and is budgeted to cost around $500 billion.

Typical trajectory of India's maiden mission to mars, Mars Orbiter Misson (MOM) has been shown below



Grissom, Young, and the Great Space Sandwich Debacle

Astronaut John Young smuggled a corned beef sandwich aboard the Gemini 3 mission in 1965, leading to unintended consequences.

Young concealed the sandwich in his spacesuit and shared it with his crewmate, Gus Grissom, during the flight. While the sandwich itself didn't cause harm, the floating crumbs posed a significant risk. In the weightless environment of space, these crumbs could have damaged sensitive equipment or been inhaled by the astronauts, leading to potential safety hazards

The incident drew criticism from Congress, who felt that the astronauts had disregarded NASA's carefully planned food protocols, potentially wasting taxpayer money. This led to stricter food regulations for future missions .

Despite the controversy, the sandwich became a part of space history, humorously dubbed the "30 million dollar sandwich" due to the cost of the mission

Source: Internet

Some interesting Anecdotes

Dr. S.P. Basavaraju

Professor of Physics (Retd.)
BIT, Bengaluru

1. When a great Economist dines with a great Physicist …

John Maynard Keynes, better known as Lord Keynes is a great British economist well known for his economic theory that is named 'Keynesian theory' in which he advocated 'Capitalistic approach for the economic development of a country'. (Apart from being a great economist, he was known to have possessed the finest private collection of '**Newton's writings**' in the world. He also served as the Director of Bank of England. His book 'Treatise on Probability' on how probability works in economics is considered a pioneering adventure.)

Once Keynes was having dinner with Max Planck. While having the food, Planck turned to Keynes and told, '*As a student, I once considered going into economics. But I decided against it - it was too hard*". Keynes relished Planck's statement and later narrated it with a vigor to his friend at Cambridge. "*Why, … that's odd*," said the friend. "*Bertrand Russell was telling me just the other day that, he'd also thought about going to economics. But he decided it was too easy*."

2. First time when Laue met Einstein …

Max Von Laue

Max Von Laue, well known (later) for his work on determining crystal structure by X-ray diffraction, became curious about Einstein when he found Max Planck was impressed by Einstein's paper on relativity that was published in 1905. Einstein had proved in his theory that, the Planck's constant 'h' was a Universal constant that it remained invariant while transformations occur between coordinate systems moving at different velocities though, space, time and energy undergo changes. Till then, for Planck, h was an adhoc constant that was needed to derive the theory for Blackbody radiation spectrum. Laue started wondering, 'Who is this man Einstein?' and decided to go in search of him especially after he talked to one of his friends by name, Carl Seeling who was to write the biography of Einstein decades later.

Laue always went for mountain climbing during summer holidays. This time, in the summer of 1906, he travelled to Switzerland. After his mountain climbing sports, he proceeded to Swiss patent office where, Einstein was working as 'Technical expert'. Laue writes about his first encounter with Einstein as, "As agreed upon by letter, I was to visit him in the patent office. In the reception room, an office worker directed me down a corridor where Einstein was to meet me coming from the other direction. I did as he had directed. But the young man who came from the opposite direction looked so different from what I expected, that I did not believe he could be the father of relativity theory. So I let him pass by me and only when he returned from the reception room did we introduce ourselves. I only know a few details of what we discussed but, I do recall that the cigar he offered me was so unpleasant that I let it fall "inadvertently' from a bridge into the

Aare river". Laue recalled that they walked together through the city. While walking, Laue spoke about the excitement in mountain climbing; however Einstein did not share the enthusiasm and remarked,

"I don't understand how anyone can wander up there"!

3. What happened that took Laue to investigate determining crystal structure by x-ray diffraction, …

In 1910, one young lad by name Paul Ewald, joined Sommerfeld as his student and started his work on, "**Dispersion of double refraction in electron lattices**". In 1912 while preparing his research report, he was not able to account for many intriguing results. Thinking of whom to approach for help, he settled on Max von Laue for, he was the optics specialist in the Institute. He approached Laue one day for the discussion. It was lunch time.

Laue invited Ewald to his home to have the discussion on dinner. As they started walking together, the discussion started anyway. They were still in the large lobby just before getting out of the institute at which time exactly, Ewald spoke the magic word **"LATTICE"** to Laue. While they were stepping out of the Institute, Ewald explained that in his analysis, he had assumed that there are oscillators with oscillations in the optical range – called optical resonators and were arranged in order in the form of a lattice. Laue asked "Why so? " as the idea of lattice was NEW to him. Ewald didn't tackle 'why' of it but explained that, in crystal, one assumes a certain kind of orderly arrangement inside it. Laue came in line with Ewald's description and asked,

"What is the distance between the resonators?"

Ewald replied that, it was very small, perhaps about a **thousandth part of wavelength of visible light** and the exact value was still unknown. He clarified anyway that the knowledge of exact separation is not required as far as his investigations are concerned and it was enough to know that, it is much smaller than the wavelength of light. Ewald continued his explanation of how he was analyzing the problem as they continued walking, but suddenly realized that, Laue was no longer giving attention to his words. Laue had sunk in his own stream of thoughts. His mind was thinking about connecting, the distance between the resonators to the wavelength of X-rays.

Perhaps pushed up by a fresh bout of thinking (and unmindful that he is in a conversation) Laue once again asked Ewald about knowing the distance between the resonators for which Ewald was to repeat the same answer he gave before. Then Laue asked, probably more as a loud thinking,

"What happens if em waves of very short wavelengths are passed through the crystal ?"

Obviously Laue had \X- rays in his mind.
Now, whether Ewald got satisfactory clarification from Laue about the problem confronting him or not, becomes immaterial. Coincidentally, Laue had just then theoretically investigated diffraction effects from line and cross-gratings. In the back-drop of this knowledge, he arrived at the conclusion that, a crystal is most likely to act as a 3-dimensional diffraction grating to X-rays.

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Activities of KPA Members from February 2024 to May 2025

Academic activities of Sri.H D Ananda from 15th Jan 2025 onwards

SL N	DATE	PROGRAM	INSTITUTION	TOPIC	REMARKS
01	20 Jan 2025	Invited talk as Resource person	Dr Ambedkar Institute of Technology, Bengaluru	Physics in play at satellite control station- Master Control Facility, ISRO,Hassan	Delivered the talk , Interactive session with students and Video show
02	22 Jan 2025	Invited talk as Resource person	Siddaganga Institute of Technology, Tumkur	Quantum Computing	Delivered the talk , Interactive session with students
03	26 Jan 2025	Chief Guest Invited talk as Resource person Science Exhibition inauguration	Vagdevi's Sammilana 2025 Holelkere, Chiradurga	Overview of Indian Space program	Delivered the talk , Interactive session with students and Video show Felicitation was done
04	31 Jan 2025	Invited talk as Resource person	Indus International School , Bengaluru	Quantum Computing for High School and PUC students	Delivered the talk , Interactive session with students
05	11 Feb 2025	Invited talk as Resource person	Sri Rajeshwari Vidyashala High School, RR Nagar, Bengaluru	Fundamentals of satellites and Rockets	Delivered the talk , Interactive session with students and Video show
06	28 Feb 2025	National Science day Chief Guest	RPA First Grade College, Rajaji Nagar, Bengaluru	Overview of Indian Space program	Delivered the talk , Interactive session with

		Invited talk as Resource person			students and Video show
07	03 Mar 2025	National Science day Chief Guest Invited talk as Resource person	Govt First Grade College, Kengeri, Bengaluru	Overview of Indian Space program	Delivered the talk , Interactive session with students and Video show
08	04 Mar 2025	Quantum Science for High School Students -9th Std Invited talk as Resource person	Freedom International school, HSR Layout Bengaluru	Quantum Computing	Delivered the talk , Interactive session with students
09	05 Mar 2025	International Year of Quantum Science and Technology along with KPA Invited talk as Resource person	SJP Govt Polytechnic , Bengaluru	Quantum Computing	Delivered the talk , Interactive session with students
10	07 Mar 2025	National Science day Chief Guest Invited talk as Resource person	ANM women college , Ballari	Quantum Computing	Delivered the talk , Interactive session with students
11	08 Mar 2025	National Science day Chief Guest Invited talk as Resource person	Rao Bahadur y Mahabaleshwarappa engg college,Ballari	Quantum Computing in AI	Delivered the talk , Interactive session with students
12	08 Mar 2025	National Science day Chief Guest Invited talk as Resource person	Rao Bahadur y Mahabaleshwarappa engg college,Ballari	Indian Space Program and Career guidence	Delivered the talk , Interactive session with students and Video show

13	13 Mar 2025	Invited talk as Resource person	Vidyavardka College of Engg, Mysore	Overview of Indian Space Program	Delivered the talk , Interactive session with students and Video show
14	17 Mar 2025	Invited talk as Resource person	SJBIT institute of Technology, RR Nagar, Bengaluru	Overview of Indian Space Program	Delivered the talk , Interactive session with students and Video show
15	24 Mar 2025	Invited talk as Resource person	Akash Institute of engg and Technology, Devanahalli	Quantum Computing	Delivered the talk , Interactive session with students and Video show
16	25 Mar 2025	NSD and Invited talk as Resource person	SJBIT institute of Technology, RR Nagar, Bengaluru	Quantum Computing	Delivered the talk , Interactive session with students and Video show
17	27 Mar 2025	One day Workshop on Science communications for B.Sc and B.Ed students	Pilukula Regional Science Center, Mangaluru	Overview of Indian Space program Quantum Computing	Delivered the talk , Interactive session with students and Video show
18	02 Apr 2025	Invited talk as Resource person	GSSS College of engg for Women, Mysore	Physics in Play at Satellite Control Stations – Master Control Facility, ISRO	Delivered the talk , Interactive session with students and Video show
19	03 Apr 2025	Invited talk as Resource person	Sri Siddartha Institute of Technology (SSIT), Tumkar	Overview of Indian Space program	Delivered the talk , Interactive session with students and Video show

A brief report on the Day National Conference on Quantum Science and Technology, Role of Artificial Intelligence in Physics Teaching and Materials Science

- Dr. P. Nagaraju, Professor of Physics and Conference Convener

A two- day National Conference on Quantum Science and Technology, Role of Artificial Intelligence in Physics Teaching and Materials Science (NCQAPM – 25) was jointly organized by Karnataka Physics Association and Vijaya College in association with PRAYOGA Institute of Education Research during 21st and 22nd March 2025 at Vijaya College, Indoor Auditorium, Basavanagudi, Bengaluru- 560004.

On the first day of the event the program started with Registration process. The Inaugural Function started with College Prayer by Vijaya College Students.

Dr. M Subramanya Bhat, Principal of the college, formally welcomed the guests. The Chief Guest:Dr. KPJ Reddy, Former Professor, IISc, Bengaluru and Chairman, Machstar Group of Companies and all the dignitaries on the stage joined with him to light the inaugural lamp. Thus the Conference got started.

Dr. P .Nagaraju, General Secretary of KPA introduced the Chief Guest and the Guests of honour. They were welcomed by offering flower Bouquets. Prof B A Kagali, President of KPA briefed about the objectives of the Conference.

The Chief Guest released the Book of Abstracts and the Souvenir and then delivered the Inaugural address. He addressed the gathering with an inspiring, insightful and enlightened speech. He expressed that the students who are attending the Conference should make use of the opportunity to upgrade themselves. He also mentioned about hypersonics and shock waves - a large number of scientists are working on these topics worldwide and especially in IISc. He said that, one has to struggle a lot to achieve one’s goal.

This was followed by Dr. H S Nagaraja, Chief Mentor, Prayoga, Bengaluru. He advised the students to take up higher studies for those who are in PG classes; and for those who have taken up research work to explore more in their chosen field.

Dr. Hari Krishna Maram, Chairman, Vision Digital India, Bengaluru said that India is not far behind in several areas of research like digital education. In Space research, India is at the fore front and lot of opportunities are ahead; it is in the hands of the students to grab them.

Dr. A M Ramesh, Chief Executive officer, Karnataka Science and Technology Academy (KSTA) spoke about the objectives of KSTA. He said that, KSTA is organizing workshops at High School to College level, in online as well as offline mode. KSTA has also conducted for I and II PU Students online classes related to their syllabii and also a few CET classes by experts. It is also conducting National Science day every year. The model making competitions are also done every year in the premises of KSTA for the students.

Dr. U T Vijay, Executive Secretary, Karnataka State Council for Science and Technology (KSCST) expressed that KSCST is offering funds to take up projects by UG and PG students. He also mentioned that P G Department of Chemistry, Vijaya College is a beneficiary of KSCST grants. The special grants are being given by KSCST to conduct events of National science day, Environmental day etc. He welcomed the Colleges to come forward to make use of the opportunity.

Dr. T A Balakrishna, Hon Secretary, BHS Higher Education Society presided over the function and in his presidential remarks, he expressed that BHS HES is always ready to encourage the Institutions under BHS HES to conduct conferences, seminars, workshops etc. so that it will help the students and teachers in their academic career and in turn help the society. He said that, it is happy to note that Prof. KPJ Reddy has worked in many areas, such as Hypersonics, Shock waves, Lasers etc. He also expressed that, BHS HES Management is ready to associate with KPA in any academic activity like the conference being held.

Prof. Nasaruth Jabeen, HOD of Physics, proposed the vote of thanks to the chief gust and all the guests, BHS HES Management committee, resource persons, sponsors, KPA members, delegates, Vijaya College teaching and Non-teaching staff, students and student Volunteers working for the success of the programme. The inaugural function concluded with a tea break.

The Academic sessions started at 11.00 am.Sessions 1and 2 were chaired by Prof. N Udayashankar, Professor at Raman Research Institute (RRI). In the 1st session, the invited talk was delivered by Prof. Apoorva D. Patel, Department of High Energy Physics, Indian Institute of Science. He talked on Quantum Technology: Directions and prospects. This talk focused on Quantum Science and Technology – UNESCO has declared 2025 as International Year of Science and Technology. In the 2nd Session, 6 oral presentations were held.

In Session 3, Sri. T S Shridhar, Joint Secretary, BHSHES, Chaired the invited talk. The invited talk was delivered by Sri Pavan Kumar A G, Software Architect, IBM ISDL Labs. He

talked on Computer vision: intuition and applications. After his talk, the chair of the session T S Sridhar, elaborated more on the applications of computer architecture.

Session 4 consisted of Oral presentations. Prof. M S Jogad, Vice President, KPA Kalaburagi Division chaired the session in which six Oral presentations were held. In Session 5- Poster Presentations was held for posters PP-01 to PP-15. The poster presentations were judged by the Jury members Dr. S N Shobha Devi, Dr. Shanthala V S and Dr. Abhiram J. The poster presentations took place in the Physics Laboratory of the college. Two Evening talks were delivered by Dr. Arvind G Kulkarni and Dr, Ashok R.

A Cultural programme presented by the students of Vijaya College took place from 6.15 PM to 07.00 PM. This was followed by sky observation with a telescope. Mr. Altaf Pasha, gave an insightful information about planets, directions, constellations etc. The participants enjoyed sky watching till 08.00 PM.

DAY 2. The academic Sessions started at 9.30 AM. In Session – 6 Prof. Chandan Kumar of IISc delivered a talk on Probing Quantum Matter by Electronic Noise. This was followed by a number of questions by the participants. He clarified their queries.

Session - 7 was chaired by Prof Somasekara S, Joint Secretary, Kalaburagi division, KPA . 6 Oral Presentations were held in the session. This was followed by the Poster Presentations in the Physics Lab for posters PP-16 to PP-29. The same jury members judged the poster presentations from PP- 16 to PP-29.

Session – 8 started at 1.45 PM. Dr. R S Keshava Murthy, Scientist (Retd), IGCAR, Kalpakkam and Prof B. Eraiah, Chairman, Department of Physics, Bangalore University, Jnana Bharathi Campus chaired the session. During this session, out of 9 participants, 7 presented their papers. Thus totally 27 oral and 29 Poster presentations were made.

The Oral Presentations were judged by the jury members: Prof B Rudraswamy. Prof S K Nataraju, Prof S P Basavaraju and Dr. Shivaram N Patil.

During the consolidation of the results, feedback session was conducted. Dr. Thejas R and Dr. Hariharan from Nagarjuna College and Sir. MVIT College respectively shared their opinions and experiences. Further, Pruthviraj N, II M.Sc. Physics Student and Tanesha Kumaraswamy I PUC Student also shared their happiness and experience of attending the Conference. A lot of useful suggestions were also given by the senior members of KPA to improve the activities of KPA and they opined that the KPA should make some efforts to improve the strength of students opting for Physics as their career. They expressed that, this

is possible by the efforts of the government and the teachers teaching Physics at PU. KPA has to approach and put some efforts in this regard.

Prof B Rudraswamy expressed the opinion that some presentations were very good and some have to improve their quality of the paper and the presentations. Dr. Abhiram expressed his feelings about Poster presentations. He said that, the arrangements for Poster presentations could have been improved and it should have been in the standard format.

The Valedictory function was held as per the schedule at 04.00 PM. Prof B Eraiah, Chairman, Department of Physics, Bengaluru University, was the Chief Guest. Prize winners of Oral presentations were announced by one of the Judges - Prof B Rudraswamy for different divisions as follows: Mr. Altaf Pasha was given the prize for the Quantum Science and Technology, Dr. Abhiram J was given the prize for the Role of Artificial Intelligence in Physics Teaching and Dr. Prathibha Prabhu B for the Materials Science.The Chief guest and the guests on the dais gave away the prizes.

In the poster presentations category, the details are as follows. The list of the prize winners was announced by the Judges. Dr. S N Shobha Devi, announced the student category, Dr. Shanthala V S announced the special prizes and Dr. Abhiram announced the winners among the faculty. The prizes were awarded to the winners by the chief guest Dr B Eraiah Principal, Dr M Subramanya Bhat, Dr. B A Kagali, Dr. B S Srikanta, Dr. A G Kulkarni, Dr. R S Keshavamurthy. Dr. R S Geetha and Dr. P Nagaraju.

Prize Winners

Category	PP No	Name	Subject Area	Prize	Prize (Repeated)
Student	PP-26	Uday B	Material Science	I	I
	PP-20	Bhuvana R	Material Science	II	II
	PP-18	Spoorthy	Material Science	III	III
	PP-24	Tanesha Kumara Swamy (11th Std) & Ojaswin Shastry (9th Grade)	Material Science	Special Prize	Special Prize
	PP-05	Mubarak Taj	Quantum Technology & AI	I	I

	PP-03	Govindaraja B P	Quantum Technology & AI	II	II
	PP-12	Prajwal Kalyan	Quantum Technology & AI	III	III
	PP-04	Harshini T	Quantum Technology & AI	Consolation	Consolation
	PP-07	Pooja Sharma	Quantum Technology & AI	Consolation	Consolation
Faculty	PP-09	Dr. Shivalinga Swamy T	Quantum Technology & AI	I	I
	PP-16	Dr. Mallikarjuna	Material Science & AI	II	II
	PP-08 & 13	Dr. Sharada Nagabhushan & Dr. Thejas R	Quantum Science (PP-08) and Material Science (PP-13)	III	III

Dr. B Eraiah addressed the gathering about the declining of strength in higher Education. The proper infra-structure / Lab equipment are not adequate and the required faculty are not available in the colleges and universities. He said that, KPA has taken up the responsibility of organizing a big event like this and thereby, the strength may improve. He also expressed that entire team of KPA deserves congratulations.

Dr. B S Srikanta Vice president, Bangalore urban division, KPA addressed the gathering about the Education system in Karnataka and about the KPA activities. He mentioned that KPA is also a contributor for the introduction of SEP by the Government.

Dr. B A Kagali mentioned that Kannada may be used at the Higher Education system as per the new National Education Policy. It is essential for effective teaching. He also thanked the Vijaya College Management, Principal and the students for the support extended in a big way for the success of the Conference of such a magnitude.

Dr M Subramanya Bhat, Principal of Vijaya College, in his presidential remarks, mentioned that KPA has done wonderful work in organizing the Conference in his College and therefore they deserve the appreciation and Congratulation. He said that, any kind of programme like this, Vijaya College is always ready to host.

Dr R S Geetha, convener, proposed the vote of thanks. She thanked BHS HES Management, KPA members, sponsors, Vijaya College, Organizing committee, which includes Dr M Subramanya Bhat, Prof Zaiba Nishath Bano, Prof. C R Shreedhar, Prof. V Jyothy, Prof. Hemalatha N (CS Dept) and all the student volunteers who worked tirelessly to make the conference a memorable one.

The conference concluded with the singing of the national anthem.

Glimpses of the Conference

Releasing the Book of abstracts of the national conference

National conference participants, Vijaya College, Bengaluru

WEBINARS HELD BY KPA DURING THE PAST THREE MONTHS

Sl no	date	Speaker	topic
1	2.2.25	Dr.A S Krishna Prasad	Structured colours
2	16.2.25	Dr.Bala Iyer	Gravitational wave astronomy
3	23.2.25	Dr.Suvrat Raju	Information fromBlack holes
4	2.3.25	Dr.R Loganayagam	Black holesas opensystem
5	16.3.25	Dr H S M Prakash	Climate change-new perspectives
6	13.4.25	Dr Pandurang Ashrit	Switchable smart thin films and nanostructures for advanced applications
7	20.4.25	Dr.S M Khened	Report on a visit to SLAC
8	27.4.25	Dr.B Rudraswamy	Particle Accelerators-Hub of talents