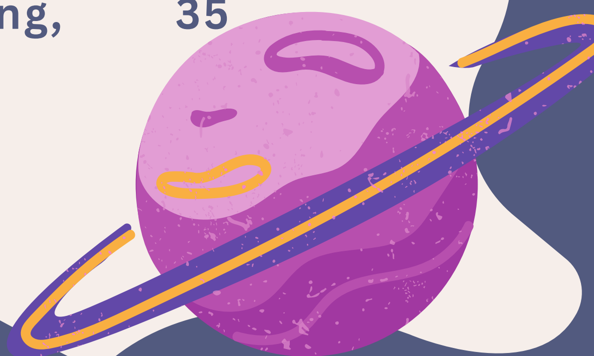
Macrocosm

Table of Contents



From the Editor

Dear Readers,

Welcome to this issue of Macrocosm, where we embark on a journey through the vast and enigmatic realm of astronomy. From the fiery birth of stars to the silent gravitational grip of black holes, this edition delves into the fundamental questions that have captivated humanity since we first looked up at the night sky.

The main purpose of "Macrocosm" is to hone students' skills which will benefit them in the future. Macrocosm focuses on both- providing exciting knowledge from Physics as well as giving opportunity to students whether they are reading or writing any article.

Chief Teacher Editor
Punita Verma

In this issue, we've curated a collection of articles that explore the cutting edge of astronomical research, inviting you to ponder the universe's grand design. We talk about various interesting topics of Physics like Pulsars, Space explorations, black holes, dark matter, gravitational lensing and mind-bending paradoxes. This will surely enlighten and inspire you!!

This issue of Macrocosm is dedicated to the insatiable human curiosity that drives us to explore the cosmos. We hope it ignites your own passion for astronomy and inspires you to ponder the profound questions that continue to challenge and inspire us.

Happy reading, and may your journey through the cosmos be filled with wonder and discovery.

From the Editor

Greetings fellow stargazers and cosmic explorers!

I'm incredibly happy and excited to present this issue of Macrocosm, a magazine born from our shared fascination with the universe. We've packed this edition with a diverse range of topics, hoping to ignite your curiosity and inspire a deeper appreciation for the wonders of astronomy and physics.

We begin our journey with the rhythmic precision of pulsars, those celestial clocks that illuminate the extreme physics of neutron stars. Then, we delve into the fascinating realm of the 5th state of matter, exploring the strange and counterintuitive behaviors of Bose-Einstein condensates.

The elusive nature of dark matter continues to intrigue us, and we've dedicated two articles to unraveling its mysteries and the ongoing search for its constituents. We proudly showcase the achievements of Space India, highlighting the nation's growing prowess in space exploration and its contributions to our understanding of the cosmos.

Chief Student Editor
Suruchi Singh

This issue also tackles the mind-bending world of paradoxes, exploring different kinds that challenge our understanding of reality. We talk briefly about gravitational lensing and thentrace the dramatic lifecycle of stars, from their birth in stellar nurseries to their spectacular finales.

For those with a taste for the theoretical, we explore the concept of wormholes, those hypothetical shortcuts through spacetime. And for those just beginning their cosmic journey, we provide a comprehensive introduction to space exploration.

But Macrocosm is more than just articles. We've included a variety of engaging content to keep you entertained and informed. Challenge your mind with our crosswords, immerse yourself in the beauty of a cosmic poem, and discover fascinating facts that will leave you in awe of the universe.

A special highlight of this issue is our exclusive interview with our esteemed faculty member, Prof. Sudha Gulati. Her insights and experiences provide a unique perspective on the world of physics and astronomy, and we're grateful for her contribution.

This magazine is a testament to the passion and dedication of the Macrocosm team. We hope you enjoy reading it as much as we enjoyed creating it. Let's continue to explore the vast expanse of the universe, one page at a time.

Clear skies and curious minds!

BEYOND THE SPOTLIGHT

When we think of physics, we often picture monumental theories and iconic figures like Einstein or Newton. But beyond the headlines, there are countless lesser-known discoveries that have played crucial roles in shaping our understanding of the universe. These stories often feature scientists who toiled in obscurity, their groundbreaking ideas overlooked or misunderstood in their time. In this article, we'll explore eight of these stories of discovery in the world of physics. From quirky experiments to surprising revelations, let's uncover the fascinating tales behind these overlooked contributions!

EUREKA MOMENT FOR PENZIAS-WILSON

It was 1964, and two astronomers, Arno Penzias and Robert Wilson, were working on a massive horn-shaped antenna in Bell Lab, Holmdel, New Jersey. They were supposed to be studying faint radio signals from space, but something kept getting in the way. No matter where they pointed their antenna, this weird background noise kept showing up—a low, steady hum that seemed to be coming from everywhere in the sky. At first, they thought it had to be some sort of interference. Maybe it was the equipment, maybe even pigeons nesting inside the antenna—something mundane like that. They spent days trying to fix it, even cleaning out the bird droppings and tightening every screw. But no matter what they did, the hum wouldn't go away.

At the same time, just a short drive away at Princeton University, a group of physicists led by Robert Dicke was chasing a different idea. They were working on the Big Bang theory—trying to figure out what the universe must've been like in its earliest moments. According to their calculations, if the universe really did start with a massive explosion, there should still be some lingering radiation from that event, though it would've cooled down over billions of years. That radiation, they predicted, would show up as a faint microwave signal across the sky.

Penzias and Wilson had no idea about the Princeton team's work, but eventually, word got out. When they learned that Dicke's group was looking for exactly what they were hearing in their antenna, a light bulb went off. Maybe the strange hum wasn't a problem after all. Maybe

Just maybe, they had stumbled upon the very thing that Dicke's team was hoping to find.
They called up Dicke, who, when he heard about the noise, immediately realized what had happened. "Well, boys, we've been scooped," he told his colleagues. Penzias and Wilson, by sheer accident, had discovered the cosmic microwave background radiation—the afterglow of the Big Bang itself.
It was a groundbreaking discovery, one that provided the strongest evidence yet for the Big Bang theory. This radiation, called the Cosmic Microwave Background Radiation (CMBR), is the remnant heat from the big bang stretched into microwave length over billions of years as the universe expanded. Its uniformity and presence in all directions were key features that confirmed that the faint hum wasn't just noise; it was a 13.8 billion-year-old echo, a relic from the birth of the universe as the relic from the universe's early stages.
In 1978, Penzias and Wilson were awarded the Nobel Prize in Physics for their discovery, and their story became a cornerstone of modern cosmology. What started as an annoying problem turned out to be one of the most important scientific breakthroughs of the 20th century.

5TH STATE OF MATTER

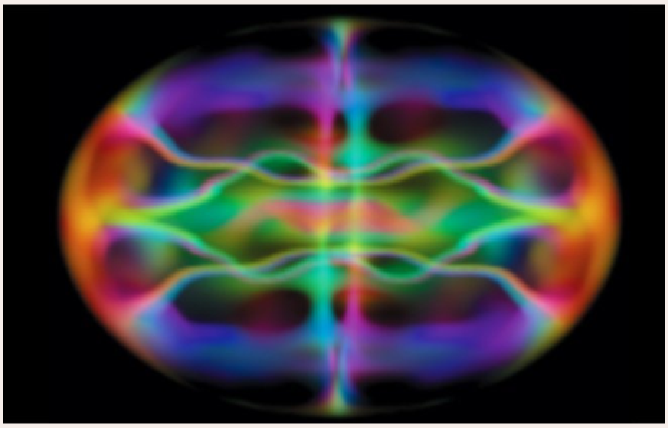
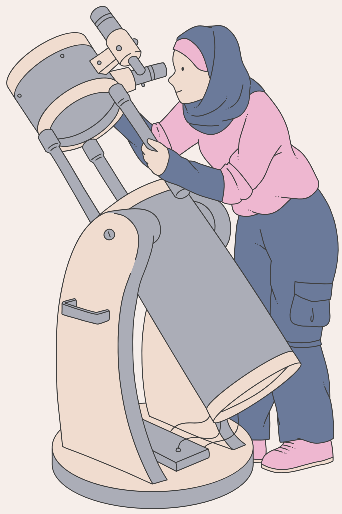


image credits: https://www.sciencealert.com/bose-einstein-condensate

In the early 1920s, Satyendra Nath Bose, a relatively unknown Indian physicist, was working as a lecturer at the University of Dhaka. At the time, quantum mechanics was still in its infancy, and Bose was deeply fascinated by the behavior of light and how it interacted with matter. One of his major concerns was the inconsistencies in Planck's law of black-body radiation. Bose believed there was something missing—an overlooked detail that would bridge the gap between the theory and observations.
It was during a lecture on statistical mechanics, while preparing his notes for the class, that Bose found a mistake in the application of classical physics to explain the properties of photons. The key, he realized, was to think of light particles—photons—not as individual entities following the usual rules of particles but as indistinguishable, meaning that switching two identical particles should not result in a new state. This was a radical departure from the existing methods of calculation.
Eager to share his discovery, Bose drafted a paper titled "Planck's Law and the Hypothesis of Light Quanta".



However, there was a problem. Bose had no way of getting his work published in a well-established journal. At the time, physics research was dominated by European institutions, and Bose was an outsider. His paper, written in English, was rejected by an Indian journal. Instead of sending the paper to another journal, he sent it directly to one of the most celebrated scientists of the time—Albert Einstein. He included a letter, humbly asking Einstein for his opinion on the new way of thinking about photons. Bose didn't know if Einstein would even read it, let alone respond.

To his amazement, Einstein not only responded but was also highly impressed by the paper. He immediately recognized the significance of Bose's work. Einstein saw that Bose's method of counting particles was revolutionary, and he extended the idea to atoms. This laid the foundation for what we now call Bose-Einstein statistics, a crucial pillar in quantum mechanics.

Einstein himself translated Bose's paper from English to German and submitted it to the prestigious journal "Zeitschrift für Physik" with a note praising Bose's insights. Bose's method of treating particles became the cornerstone for understanding the behavior of an entirely new state of matter—the Bose-Einstein condensate, which was experimentally confirmed decades later.

SYMMETRICAL IT IS!

It was the early 20th century, and mathematics was a world largely dominated by men. In the midst of it all was Emmy Noether, a brilliant but underappreciated woman who would go on to change the very foundation of physics. The story of her groundbreaking discovery began around 1915 when she joined David Hilbert's team at the University of Göttingen in Germany. At the time, Hilbert and other physicists, including Albert Einstein, were grappling with the intricacies of general relativity. Einstein's equations were beautiful and powerful, but there was a lingering issue: they couldn't explain why certain physical quantities, like energy, seemed to be conserved in the vast framework of curved spacetime.

Noether, being the mathematical genius she was, took on the challenge. With an uncanny ability to see patterns and connections where others couldn't, she realized that this wasn't just an issue of physics—it was a problem that could be solved through the language of symmetry.

Her insight was simple yet profound: if a system has a symmetry, then there must be something about it that stays the same—something conserved. She developed what we now call Noether's theorem, and it elegantly showed that for every symmetry in nature, there is a corresponding conservation law.

For example, if the laws of physics are the same today as they were yesterday (a symmetry in time), then energy must be conserved. If the laws are the same here as they are in another part of the universe (a symmetry in space), then momentum must be conserved.

Her theorem tied together so many pieces of physics that had previously seemed disconnected. It was revolutionary, but the world didn't immediately recognize it. In fact, her work was initially overlooked, partly because she was a woman in a field that wasn't ready for her genius.

Yet, she never wavered. Her theorem slowly began to make waves, first in the mathematical community and then in physics. Over time, physicists realized that Noether's work was the key to understanding the symmetries of the universe. Her theorem became the bedrock for theories of quantum mechanics, particle physics, and even string theory.

JOCELYN BELL AND PULSAR

In 1967, Jocelyn Bell was just a young PhD student at the University of Cambridge, working under the supervision of Antony Hewish, a well-respected astronomer. Her task was not glamorous—it involved sorting through mountains of data from a brand-new radio telescope they had built to observe distant quasars. Jocelyn spent hours painstakingly poring over the data, looking for tiny blips in the sea of radio noise. She often described the process as like "sifting through piles of hay, hoping to find a needle." But one day, she found something strange—a peculiar signal that was unlike anything she'd seen before. It was a regular pulse, repeating with astonishing precision, once every 1.33 seconds.

At first, Bell was perplexed. This wasn't the kind of signal quasars produced. In fact, it didn't fit any known astronomical source.

Jocelyn recorded the anomaly and took it to her supervisor, but Hewish was skeptical. In fact, everyone in the department was. They joked about it, calling it "LGM-1," short for "Little Green Men," because they half-seriously thought it could be a signal from an alien civilization. The precise, rhythmic nature of the pulses was unlike anything nature had ever shown them before.

But Jocelyn wasn't convinced it was extraterrestrial. She knew there had to be a scientific explanation. So she did what good scientists do; she kept observing, week after week, collecting more and more data. Soon, she found another signal, and then another, from different parts of the sky. The signals were all identical, regular, rhythmic, and pulsating at a constant rate.

Slowly, the truth began to reveal itself. Bell had discovered a new type of celestial object: a rapidly spinning neutron star emitting beams of radiation. These stars, known today as pulsars, were a major breakthrough in astrophysics. Pulsars had been predicted theoretically, but no one had ever observed one, and certainly not in such detail.

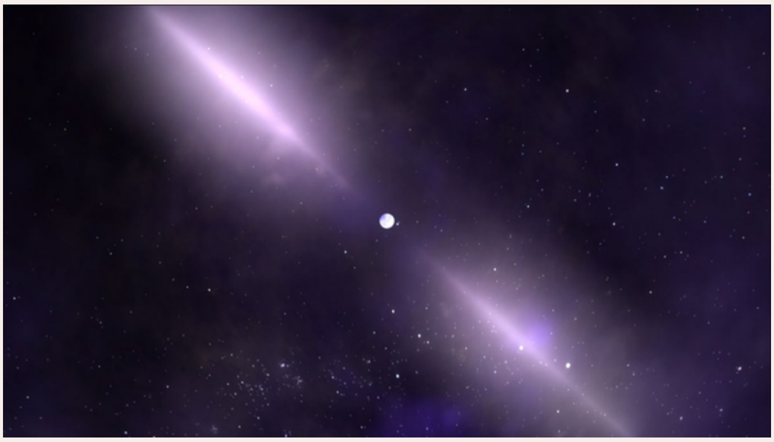


Image credit: NASA's Goddard Space Flight Center

Yet, when it came time for recognition, the credit did not fall on Jocelyn. Instead, her supervisor, Antony Hewish, along with Martin Ryle, was awarded the Nobel Prize in 1974 for the discovery of pulsars. Jocelyn, the one who had actually identified the signals and worked relentlessly to prove they were real, was left out of the recognition.

Jocelyn Bell's humility didn't diminish the importance of her discovery. Over the years, pulsars have become crucial to our understanding of the universe, aiding in everything from tests of Einstein's theory of relativity to mapping the structure of the galaxy.

CAN WE DETECT GRAVITATIONAL WAVES?

In the 1960s, Joseph Weber, a physicist at the University of Maryland, set out on a quest that many of his peers considered impossible: he wanted to detect gravitational waves—ripples in the fabric of spacetime, predicted by Einstein's general theory of relativity in 1916. Einstein himself had believed that these waves were so weak that they might never be detected. But Weber wasn't deterred. He had a vision that one day, humans could "listen" to the universe through these waves, capturing cosmic events like colliding black holes and exploding stars.

Weber's method was bold and unconventional. He built large cylindrical bars of aluminum known as Weber bars, designed to resonate when a passing gravitational wave disturbed them.

image credits: https://www.sciencealert.com/bose-einstein-condensate

These bars were suspended in isolation, shielded from external vibrations, and fitted with sensors to detect any minute changes. Weber believed that if a gravitational wave passed through Earth, it would slightly compress and stretch spacetime, causing his bars to ring with the tiniest of vibrations. In 1969, Weber announced he had detected signals that could be gravitational waves. The physics community was electrified. If Weber was right, it would be one of the most groundbreaking discoveries of the century. But doubts quickly surfaced. Many believed Weber's results were artifacts—noises from vibrations, not cosmic signals. Weber himself never wavered in his belief, but by the 1970s, most of the scientific community had moved on, and Weber's reputation suffered.

But the story didn't end there. While Weber's bars hadn't proven successful, they ignited an interest in gravitational waves that wouldn't die. Physicists realized that if they wanted to detect these faint signals, they would need something far more sensitive than Weber's bars.

Enters the Laser Interferometer Gravitational-Wave Observatory, better known as LIGO. It was the brainchild of a small group of physicists in the 1980s. LIGO was a massive project. Many doubted that it would ever succeed. After all, even Einstein himself had doubted whether gravitational waves could be detected. But the LIGO team pressed on, building two enormous facilities, one in Washington State and another in Louisiana, with four-kilometer-long arms that stretched across the landscape.

For years, LIGO gathered data, but the results were inconclusive. Some wondered if it was just another version of Weber's failed dream. Then, on September 14, 2015, everything changed. At 4:50 a.m., LIGO detected its first gravitational wave. It came from two black holes, over a billion light-years away, spiraling into each other at nearly half the speed of light before merging into one.

In February 2016, the discovery was announced to the world. Gravitational waves were real, and for the first time, humans had directly detected them. Today, LIGO continues to capture these cosmic whispers, opening a new era of astronomy. Weber's name, once surrounded by skepticism, now holds a place of honor in the long, winding journey to understand the universe.

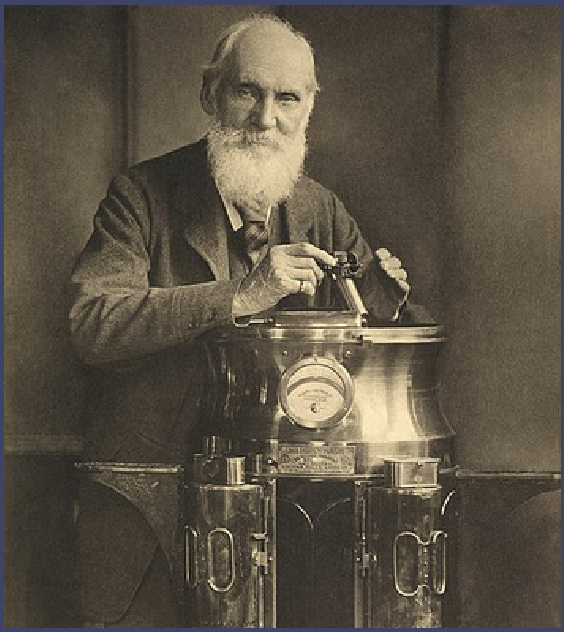
Dipakshi Sarma

B.Sc (Hons) Physics,

3rd Year

The Search for Dark Matter

Uncovering the Universe's Secrets: The Search for Dark Matter



Many of our supposed thousand million stars
perhaps a great majority of them
may be dark bodies
- lord Kelvin

One of the biggest unanswered questions in contemporary physics is dark matter. Because of its gravitational pull on galaxies and galaxy clusters, scientists are positive that it exists even though it has never been directly spotted. Indeed, it is estimated that dark matter accounts for roughly 27% of the entire mass-energy composition of the universe. Even so, it is still elusive and unobservable by our s still elusive and unobservable by our most potent telescopes and detectors, despite its supremacy in the universe. Dark matter is a form of matter that does not emit, absorb, or reflect light, making it invisible and detectable only through its gravitational effects on visible matter. It is thought to make up about 27% of When astronomer Fritz Zwicky found that galaxies within clusters were traveling more quickly than would be predicted from the visible matter there, he came up with the phrase "dark matter" in the 1930s. These galaxies should have flown apart if the only force acting on them was the gravitational pull of the visible matter. Zwicky postulated that the gravitational attraction required to hold the galaxies together was coming from some invisible substance, or dark matter. The existence of dark matter has now been confirmed by a number of lines of evidence. For instance, galaxies' rotation curves reveal that stars in their periphery travel at surprisingly rapid rates. These stars ought to be expelled from their galaxy if there were only visible substance. Rather, they seem to be held in place by the extra gravitational pull of dark matter.

The Search for Dark Matter

Although the existence of dark matter is known, scientists have had difficulty directly detecting it. This is due to the fact that dark matter is invisible to traditional telescopes since it does not emit, absorb, or reflect light. It is very hard to detect since it interacts with conventional matter mostly through gravity and maybe the weak nuclear force, not through

electromagnetic interactions. The WIMP (Weakly Interacting Massive Particle), a hypothetical particle that interacts solely through gravity and the weak nuclear force, is one of the most well-known dark matter possibilities. To find these elusive particles, a lot of experiments are being conducted. To create WIMPs, for instance, particles are being smashed together at high energies at CERN's Large Hadron Collider (LHC). Similar to this, underground labs like South Dakota's LUX-ZEPLIN experiment are studying the infrequent encounters of WIMPs with regular matter in an effort to find them. The axion, a much lighter particle with extremely weak interactions, is another contender. By examining their possible impacts on electromagnetic fields, experiments such as the Axion Dark Matter Experiment (ADMX) are trying to identify these particles. Alternative Hypotheses and Difficulties Although axions and WIMPs are the most prominent dark matter contenders, other theories have also been put forth. One is Modified Newtonian Dynamics (MOND), which casts doubt on the existence of dark matter entirely by speculating that the rules of gravity may alter at enormous scales. However, some cosmic occurrences are difficult for this theory to explain, and dark matter is still the most frequently accepted explanation.

The detecting techniques present additional difficulties. Finding the interactions between dark matter particles and conventional matter is like trying to discover a needle in a haystack since they are so uncommon. The majority of tests need a great deal of time and work, as well as incredibly sensitive equipment that can pick up tiny signals.

Research on Dark Matter's Future One of the most fascinating and ambitious research projects of our day is the search for dark matter. New experimental methods and technological developments are improving our understanding. Scientists are hoping that the mysterious dark matter particles will ultimately surface as they improve their detectors and search strategies. Understanding dark matter is essential for understanding the very fabric of reality as well as for understanding the behavior and structure of the cosmos. Even though the search is difficult and never-ending, we are getting closer to solving one of the universe's greatest mysteries with every new discovery.

Reference:
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Sonu
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SPACE INDIA:
A Frontier in Focus

On 21 November 1963, India flew the first sounding spacecraft from the small village of Thumba. Thumba is a coastal area located near Thiruvananthapuram, the capital of the state of Kerala. Dr. Vikram Sarabhai, the father of the Indian space program, had seen a small church near the village. He felt that this place was beyond the Earth's magnetic meridian, which would be suitable for a spacecraft to fly and go into space.

At that time, when there was not much advancement in technology in India, there were neither televisions, nor phones, only telephones were used for communication, and those too were owned by only one person. Indian space was preparing for the dispatch of the first communications satellite, the Ariane Passenger Payload Experiment (APPLE), in 1977–83 at the Mission Control Center in Sriharikota. ISRO did not have many facilities, and to provide a non-magnetic environment, and due to the impedance matching problem, TT&C, had come up with the idea that the Apple Mission should be mounted on a bullock cart to conduct antenna tests in open fields. On 19 June 1981, India launched the first geostationary laboratory communication satellite project, which Ariane-1 launched from Kourou, French Guiana.

This successful mission led to the development of a large constellation of satellites in the INSAT and GSAT series, which helped the country and brought a revolution in the technological and economic growth of India. On 19 April 1975, India's first satellite was launched, which was named after the great mathematician and asttonomer Aryabhatta. Kosmos-3M was launched from a Soviet spacecraft launch and development site in Astrakhan Oblast using

Image Courtesy: www.thebetterindia.com:

Kosmos-3M vehicles.

ISRO had built the Aryabhatta satellite. The purpose of the spacecraft was to conduct experiments in astrology, agricultural science, and solar physics.

CHANDRYAAN MISSION

On November 8, 2008, Chandrayaan-1 was launched aboard the PSLV-C11 launch vehicle and successfully placed the spacecraft in lunar orbit. On November 14, 2008, the MIP (Moon Impact Probe) separated, hitting the Moon's south pole in a controlled manner. On 29 August 2009, ISRO officially declared the mission aborted after almost a year due to a series of problems and communication failures. Chandrayaan lasted 312 days against the scheduled two years, and the biggest discovery of Chandrayaan-1 was the widespread presence of water molecules in the lunar soil. India emerged as the fourth country in the world to hoist its flag on the surface of the Moon.

Image Courtesy: www.ndtv.com

ISRO launched the Chandrayaan-2 mission on July 22, 2019, from the Satish Dhawan Space Centre, Sriharikota. The objective of the mission was to make a soft landing on the surface of the Moon. But before the space agency landed on the moon, all contact with Vikram Lander was lost. This mission is considered successful because this mission was not a complete failure. If the lander had successfully landed on the moon, India would have joined the list of countries that have reached the moon. Vikram Lander was tilted to 410 degrees instead of the fixed position of 55 degrees. Because of this tilt, it lost contact even before landing on the Moon. The lander was just 2 kilometers away from the landing surface. Which was very little. Only in the last stage was the contact lost, and it crashed on the Moon.

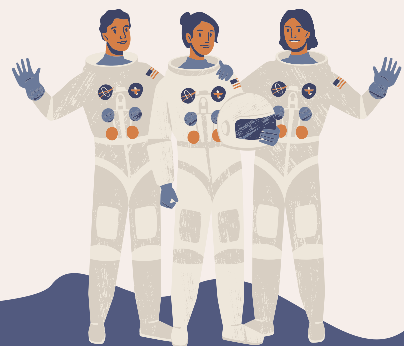
On July 14, 2023, India launched Chandrayaan-3 from Satish Dhawan Space Center (SHAAR), Sriharikota. The objective of the mission is to demonstrate the safe and natural environment on the lunar surface. The rover has been imaged on the Moon and conducts in-situ scientific experiments. The spacecraft will land on the lunar surface near the south pole on 23 August 2023 under the guidance of the lander Vikram and the rover. With the comfort of LM equipped with LM, the landing was done smoothly around the moon, and India created history in the whole world.

MANGALYAAN MISSION

On November 5, 2013, PSLV-C25 was launched on the Mars Orbiter Mission (MOM), India's first interplanetary mission to Mars. Designed mission life 6 months ago, but (Mom) completed 7 years in her orbit on September 24, 2021. The mission was intended to include the manufacturing of spacecraft to demonstrate India's design launch systems, spacecraft manufacturing, and operational structures. ISRO Florida has become the fourth space agency to have a satellite in Mars orbit.

The mission began in November 2013 and was launched into Mars orbit on 24 September 2014. The Mangalyaan mission had created a history in the whole world because India was the first country that had directly reached Mars once.

Image Courtesy: www.launchpadias.com



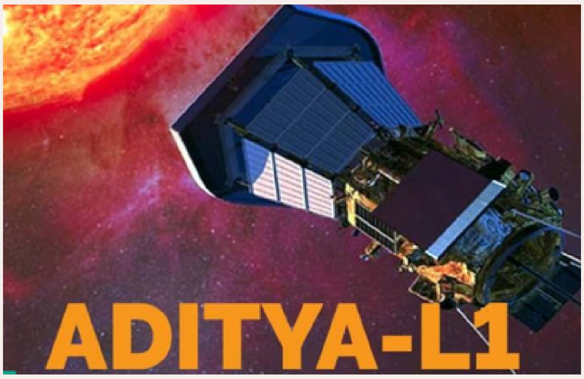


Image Courtesy: www.moneycontrol.com

GAGANYAAN MISSION

The Gaganyaan Mission is India's first human spaceflight mission under which four astronauts, Prashant Nair, Angad Pratap, Ajit Krishnan, and Shubhanshu Shukla, will go and travel in space. LVM-3 launch vehicle. Earlier called GSLV Mk-III, it is a three-stage rocket. This mission has to be sent by the end of 2024 or the beginning of 2025. However the chairman of ISRO, Somanath, said to ensure crew safety as challenges in developing homegrown technology for the mission, the mission will be delayed no earlier than 2026.

ADITYA L1 MISSION

ISRO previously launched the Surya mission Aditya-L1 on PSLV C57 from the second launch pad of the Sriharikota Space Center on 2 September 2023.

The mission will primarily study the chromosphere (the atmospheric layer just above the Sun's surface) and the heat and hot winds emitted from the sun's corona, and what effect the sun's rays have on the ozone layer and the local environment.

Image Courtesy: www.launchpadias.com

India has launched approximately 150 satellites into space so far, which is a great pride. India's space journey started with a bicycle, which today is sending Indian satellites to the Moon, Mars, and the Sun. The journey of sending satellites to space will continue in the future.

India has launched many historic missions from Active Operational Launch Vehicle, and many missions are successful, and one of the biggest and most successful among them has been the Mangalyaan and Chandrayaan-3 missions, which no one in the whole world has been able to do.

Sonali Kumari
B.Sc (H) Physics
III Year

What lurks in the shadows of Universe?

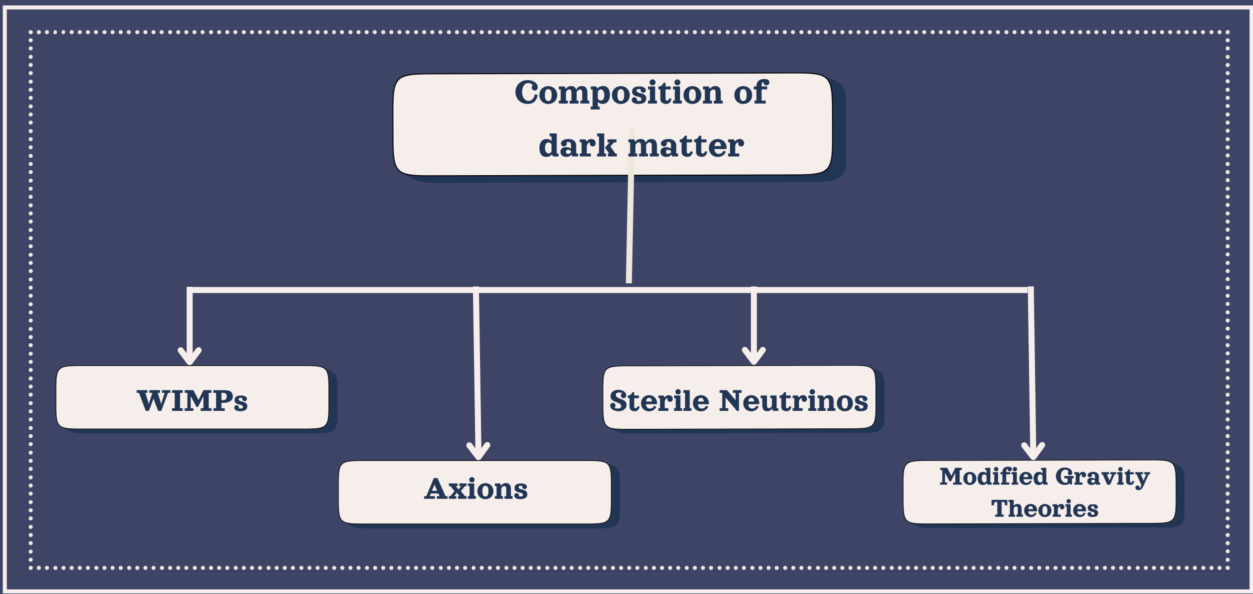
Imagine a universe where most of the matter is invisible, like a ghost that helps make galaxies and groups of stars but is hard to see. This mysterious stuff is called dark matter.

It doesn't interact with light or any other kind of energy, so it's really hard to detect; scientists can only guess it's there by studying its gravitational effects on the matter we see. It is thought to be "cold," meaning it moves slowly compared to the speed of light, and its particles are believed to interact only weakly with ordinary matter and with each other.

Image credits: https://www.canva.com/ai-image-generator/

The story of dark matter started a long time ago when astronomers noticed that galaxies were spinning too quickly. They did some math and figured out there had to be more stuff there than we could see. This made them think there might be a kind of matter that doesn't shine or glow, so we can't see it with normal telescopes. Some scientists think dark matter might be made of special particles called WIMPs, axions, or sterile neutrinos.

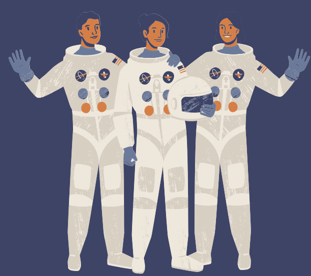
Perhaps the laws of gravity break down on cosmic scales, or perhaps there are other, yet-to-be-discovered particles or forces at play. These particles might have been made a long time ago and could still be around, but we haven't found any yet. There have been many experiments trying to find them, but they haven't been successful. Our search for dark matter shows how curious humans are and how much we want to learn new things.



The future of dark matter is exciting. Scientists are using new tools and ideas to learn more about this mysterious stuff. If they find out what it is, it could change how we understand the universe, gravity, and our place in it.

You're an avid reader or a binge-watcher of sci-fi series? These books and shows offer a fascinating exploration into the mysterious realm of dark matter.

- **Dark Matter**
- **His Dark Materials**
- **The Three-Body Problem**
- **Lost in Space**



Afreen Chaudhary
B. Sc (Hons) Physics
2nd Year

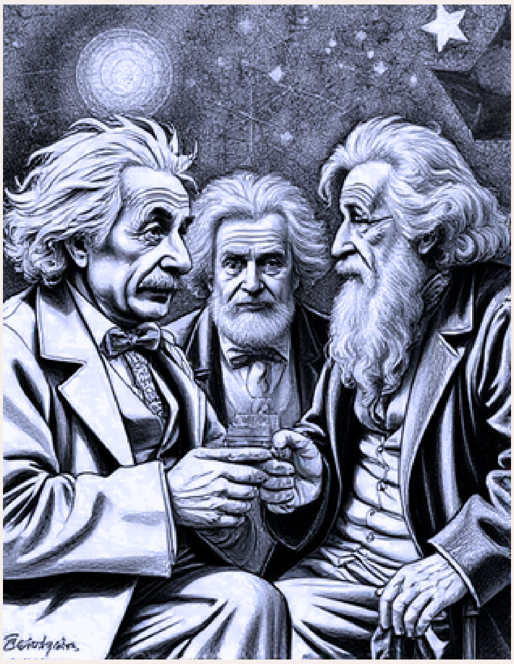
Brainbuzz

Science Facts

- In Quantum Mechanics, even the simple act of observation can change the behaviour of particles.

- Due to gravitational and special relativistic effects, time appear to pass slower near massive objects or at high speeds.

- The laws of quantum mechanics suggest that information cannot be destroyed, but the laws of general relativity imply that it can be lost in black holes.



Particles Can Behave Differently When Observed

When it comes to the quantum world, things can get pretty weird. Particles like electrons behave as waves both when we're not looking at them and when we are, called duality by physicists. This property is due to the fact that particles appear differently depending on whether or not an observer is present. For example, an electron appears as a particle when viewed using a detector, but behaves as a wave if observed without being detected. However, you will find it shows the properties of the wave when you are not observing with a detector. This can be explained by the double-slit experiment.

-Gaurangi Gaur
B. Sc (Hons) Physics
1st Year

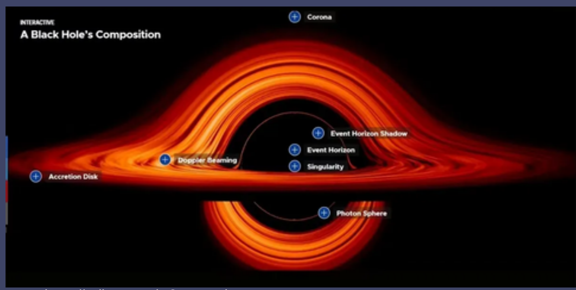
Science Facts

- The Earth is about 4.5 billion years old-but that's only a third of the age of Universe - which is 13.5 billion years old!
- There are more stars in the universe than grains of sand on all the beaches on Earth!
- There is an Asteroid called Chariklo in our solar system that has rings like Saturn.
- If you can spot the Andromeda Galaxy with your naked eyes, you can see something 14.7 billion miles away!
- The universe has no centre and is expanding every second - making it impossible to reach the edge.
- A black hole of the size of an atom has the mass of large mountain.
- It takes photon on average 170,000 years to travel from the core of the Sun to its surface!
- The moon is the reason why we have tides and waves on earth. Along with the sun, it moves billions of water each day.

-Mahi Chauhan
B. Sc (Hons) Physics
1st Year

INTO THE VOID

Black holes, once considered cosmic monsters, are now perceived to be mystifying and wonderful places in the universe. What some call 'cosmic vacuum cleaners' are places in space where gravity is so strong that nothing escapes—not even light.



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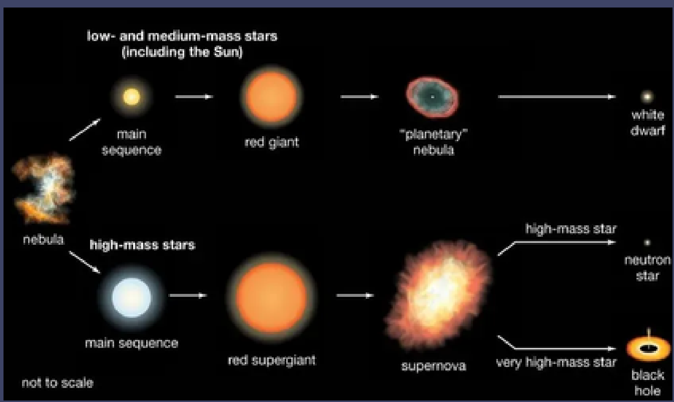

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- <u>The Black Hole's Creation</u>

It is a common understanding that black holes are formed when massive stars run out of fuel and collapse. At the end of its life cycle, a star's core is incapable of supporting any further weight coming from gravity once the core's nuclear fuel is exhausted. The beauty of a collapsing core is that its density doesn't remain the same. Rather, the axis of gravity is shifted towards a point of zero volume. With this, enormous gravitational pull is created, which absorbs the other useful particles around it.

- <u>The Horizon of Events</u>

The term event horizon refers to the boundary of a black hole. This is the point at which nothing turns back; everything crossing the event horizon eventually gets sucked into the singularity. The event horizon can be referred to as that area in space-time where the escape velocity surpasses the speed of light; it isn't, of course, a surface in space.

- ## Different Types of Black Holes

1. **Stellar-mass black holes: They are formed in the collapse of very heavy stars. Its masses are typically of the order of several to tens of solar masses.**
2. **Supermassive black holes: These are with masses varying from millions to billions of times that of the sun and are found at the center of galaxies.**
3. **Intermediate mass black holes: black holes of intermediate masses between the two extremes that are stellar-mass and supermassive blackholes— are few in number and remain a topic of debate regarding their existence.**
4. **Primordial Black Holes: They could offer insights into the conditions of the early universe and the nature of dark matter.**

https://vajiram-prod.s3.ap-south-1.amazonaws.com/Black_Hole_Types_892c65f4a9.webp

- ## Impact of the Black Hole

Black holes play a very important role in the evolution of galaxies. Supermassive black holes can even influence the development and distribution of stars and gas in galaxies through their gravitational pull. Black holes may also serve as tremendous sources of energy when matter falls into them by releasing radiation in various wavelengths, such as X-rays.

- ## The Scope for Black Hole Research

Much has been gained for our understanding of black holes despite many unanswered questions found within them. With advanced telescopes and theoretical models, scientists are still trying to decipher these mysterious objects. Further study might teach more of the nature of gravity, how galaxies form, and what the ultimate end of the universe is.

~ Shweta Sharma
Bsc.(H) Physics
II-year (3rd-sem)

At the Edge of Chaos

"Not only is the Universe stranger than we think, it is stranger than we can think."

— Werner Heisenberg

As we delve deeper into the captivating world of physics, we frequently encounter paradoxes that question our perceptions and push the boundaries of our comprehension. These fascinating situations not only show the strange aspects of the universe but also urge us to ponder profound questions about reality, existence, and the essence of life. Encompassing subjects from quantum mechanics to the vastness of the universe, these paradoxes offer insights into the intricacies at the heart of physics, encouraging us to delve into and value the enigmas that still captivate both scientists and philosophers.

- ## Schrödinger's cat

Schrödinger's cat is often misunderstood; it's not a true paradox but a thought experiment that illustrates the bizarre nature of quantum mechanics when applied to everyday life. Picture a cat inside a sealed box equipped with a device that can release a fatal gas. The probability of this gas being released is 50%, suggesting the cat has a 50% chance of being alive or dead. According to quantum mechanics, until we peek inside the box, the cat exists in a state of superposition, being both alive and dead simultaneously. This idea challenges our intuition, as we know a living being cannot truly occupy both states. Thus, we find ourselves in what feels like a paradox, pushing us to grapple with the oddities of quantum behaviour

- ## Blackhole information paradox

The Black Hole Information Paradox presents a compelling conflict between the realms of quantum mechanics and general relativity. Stephen Hawking famously posited that black holes emit Hawking radiation and can eventually evaporate. However, this radiation doesn't carry any information about the matter that once fell into the black hole. Quantum mechanics, on the other hand, tells us that information is never lost. This creates a puzzling scenario: if a black hole fully evaporates, the information about everything that has entered it also disappears, which contradicts the principle of unitarity. If we accept that information can be lost, we risk undermining quantum mechanics itself. Conversely, if information escapes, it forces us to rethink our fundamental understanding of black holes and gravity.

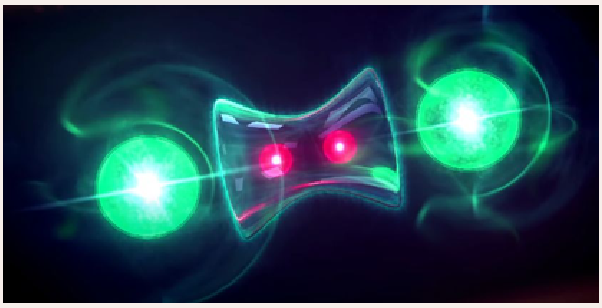
Twin paradox

The Twin Paradox offers an

intriguing thought experiment rooted in Einstein's theory of special relativity. Imagine two identical twins: one remains on Earth while the other embarks on a journey through space at nearly the speed of light. Upon returning home, the traveling twin discovers they have aged far less than their sibling. This unexpected outcome results from time dilation, a phenomenon where time moves more slowly for those traveling at relativistic speeds compared to those at rest. While it feels counterintuitive from a classical standpoint, this scenario aligns perfectly with relativity's predictions. The paradox invites us to rethink our intuitive understanding of time, illustrating that it is not a fixed entity but varies based on velocity and relative motion. Remarkably, experiments with high-speed particles and precise atomic clocks have validated these predictions.

- **EPR paradox**

The EPR Paradox, named after the renowned physicists Einstein, Podolsky, and Rosen, raises profound questions about the completeness of quantum mechanics. It centres on quantum entanglement, where two particles become intertwined in such a way that the state of one immediately influences the state of the other, regardless of the distance separating them. Einstein famously referred to this phenomenon as "spooky action at a distance," as it seemed to defy the principle that nothing can travel faster than the speed of light. The paradox prompts us to consider whether quantum mechanics is missing something essential or if our understanding of reality permits faster-than-light interactions. Nevertheless, experiments validating Bell's Theorem have confirmed that quantum entanglement is genuine and does not violate relativity. The EPR Paradox continues to stimulate philosophical and scientific debates, challenging our notions of locality, causality, and the fundamental nature of reality.



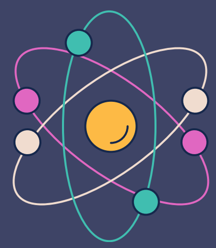
Still from an animation of a NIST quantum entanglement experiment conducted in 2013. (Yiheng Lin/NIST/YouTube)

- **Fermi paradox**

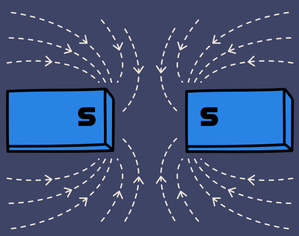
The Fermi Paradox encapsulates the tension between the high probability of extraterrestrial civilizations existing and the striking absence of evidence for their presence. Considering the vast number of stars in our galaxy, many with potentially habitable planets, one would expect intelligent life to have emerged elsewhere. Yet, despite our extensive searches, we have not detected any signs of extraterrestrial life—no signals, no probes, no visits. This raises a compelling question: where is everybody? Possible explanations range from the idea that intelligent life is incredibly rare or short-lived to the notion that advanced civilizations may be deliberately avoiding us or simply too distant for us to detect. The Fermi Paradox continues to provoke discussions about the existence of life beyond Earth and our understanding of cosmic scales.

Chhavi Jhawar
B.Sc (Hons) Physics,
3rd Year

The Physics Catastrophe



I thought I'd master physics, a breeze I assumed,
But the laws of motion had me quickly doomed.
Newton's apple? Sure, it fell from the tree—
Just like my grades, tumbling down on me!



F = ma, that seemed pretty clear,
Until friction appeared, bringing up the rear.
Momentum's conserved, or so they say,
But mine just vanished halfway through the day.

Then came gravity, strong and unkind,
It pulled on my will and twisted my mind.
Satellites orbit, planets align,
Meanwhile, I can't even follow the sine!

Energy's conserved? What a cruel jest!
Mine's always lost during every test.
Potential, kinetic, they switch up so fast—
Like Schrödinger's cat, is it future or past?

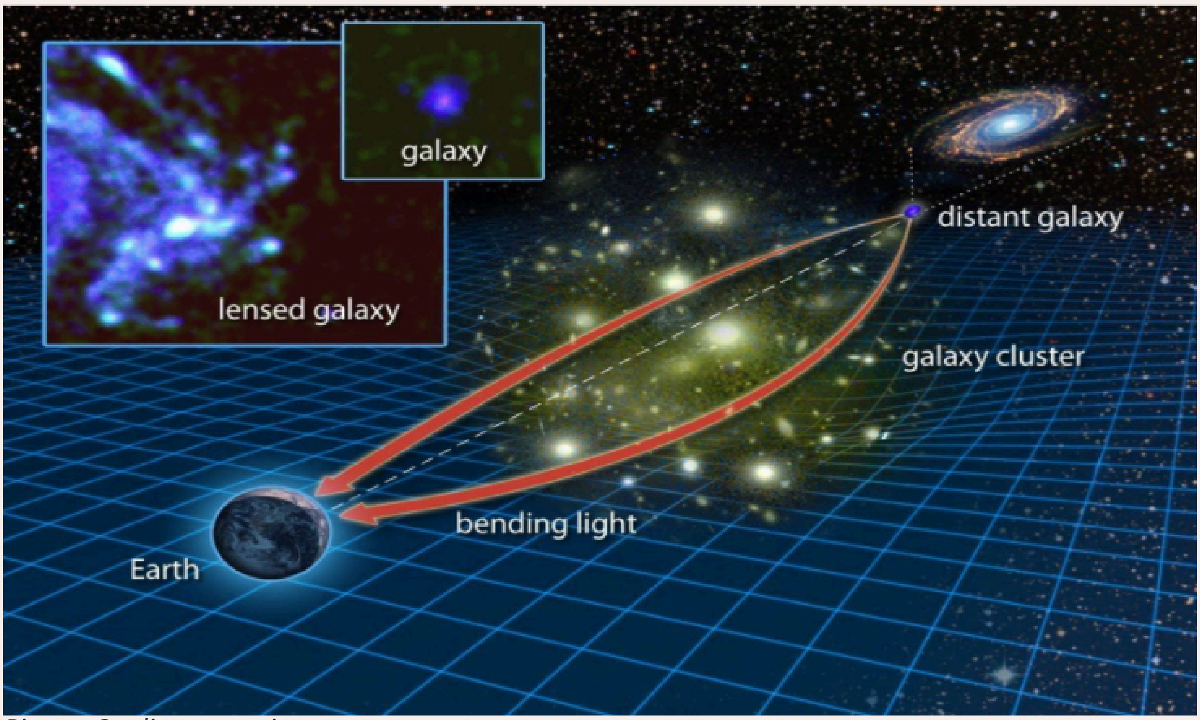
Thermodynamics left me sweating in class,
"Entropy's rising!" they yelled as I passed.
Heat engines, oh great, more to unwind,
Turns out they work, but not for my mind!

Relativity warped both my brain and the clock,
Einstein said, "Just ride the space-time shock!"
Light bends, time slows, in a cosmic spin,
While I wonder: "Will this semester ever end?"

So here's to physics, a wondrous delight,
Where the rules bend but never quite right.
I'll chase after particles, forces, and light,
And pray the exam doesn't exceed escape height.

Tanishka Thapa
B.Sc (Hons) Physics,
1st Year

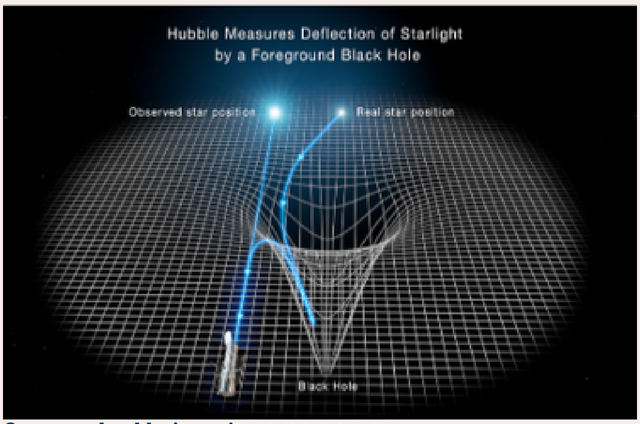
Love in the time of Relativity:
GRAVITY & LIGHT'S COSMIC WALTZ



Picture Credits:www.pinterest.com

Hey there, You must've read the title and wondered what this article is about. I'm sure you must have heard about the black holes. One of the most important property of a black hole is that they absorb light, we can see light getting sucked up in a spiral way inside the black hole and one can only see a ring kind of structure around it. This is how we locate that black hole in the dark galaxy. But have you ever wondered why this phenomenon even happens in the first place? Why is the blackhole affecting the light in such a manner?? Which laws of physics govern this phenomenon??

This happens because "gravity bends the light". Another important property of blackhole is that they have enormous gravitational force- they attract everything to their core. This gravitational force bends the light that was just trying to pass from nearby and attracts it to its core, hence deviating light from its original straight path. Now the confusion begins "Since, light is massless then according to Newton's laws it shouldn't be affected by gravity, then why does gravity bend the light??" Well, I can say that the love gravity has for light is so strong that it bends it. Just kidding!!! Well, in very simple terms, this happens because the space-time fabric is curved near objects with high mass and since the light travels along this fabric, it bends wherever the fabric is bend. This is what the General Theory of Relativity explains. According to it, everything written above is complete crap. The gravity doesn't have any affect on light . In fact, the gravity doesn't even exist in the first place, the gravity is not a force but a mere illusion!!! (even light lives in delulu, sed) I know this is hard to accept in the first place, but once you accept this fact; things will start making a sense to you and it will be a lot easier to understand what I'm saying.



Courtesy: huublesite.org

Now back to the previous story, think about objects traveling on a straight line path through spacetime. It just so happens that spacetime is curved around massive objects, so that straight line path doesn't look like a straight line and we observe that the trajectory of object is curved due to gravity, this is what is happening in the case of Black-hole. It is all a matter of perspective. We perceive that the light is bending because the gravitational force of black holes is huge but instead the light bends simply because it is travelling along space-time which is curved greatly around a blackhole.

Matter tells spacetime how to curve, and spacetime tells matter how to move.

Courtesy:https://www.physics.utoronto.ca/~jharlow/teaching/astrophys03/geodesic.html

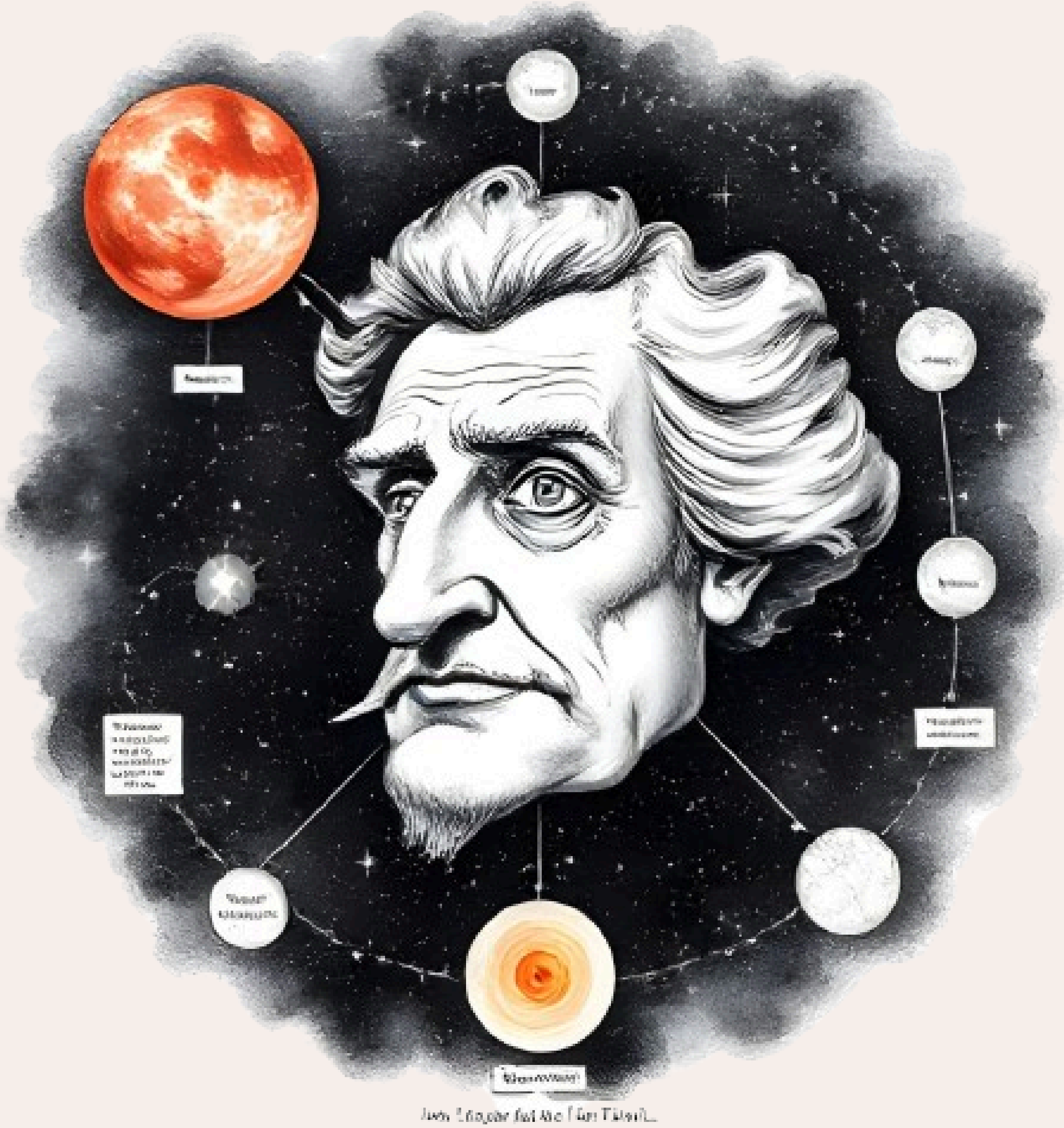
Let us now try to understand how gravity is not a force and how the bending of light is not caused by it. Let's take the trajectory of airplane as an example. Airplanes always try to fly the shortest route between cities. Essentially, they just go in a straight line. But since the Earth's surface is curved, the shortest path doesn't look like a straight line. These shortest paths over curved surfaces are called geodesics, and we use that same word, geodesics, for the straight-line paths followed by inertial observers through curved spacetime.

Let's take another analogy. Imagine you and a friend are standing on two longitudes a thousand kilometers apart on the equator. Now you both start walking towards north. Over time, you will come closer together, ultimately bumping into each other at the North Pole. It's as though there was a force pushing you together. But you didn't feel a force, and your friend didn't feel a force. Gravity is just like that force. It doesn't actually exist. You and your friend met each other at the North Pole because their path was curved.

Phew!!! I know it is compelling to look at gravity in this new way. It will take some time to fully understand and get a "feel" of it, so don't limit yourself and dive deeper into this topic if you are interested. For now, I can only tell you that this phenomenon where light is bended in the presence of gravity is called "gravitational lensing" which is just a name for the visual effect that we are observing.

By Suruchi Singh
B. Sc (H) Physics III Year

The Lifecycle of Stars



*Formation, Fusion, and Fate*

The Birth and Life Cycle of Stars

In the vast expanse of the universe, stars are born from massive clouds of gas and dust known as nebulae. A nebula is a giant, diffuse cloud primarily composed of hydrogen and helium, the fundamental building blocks of stars. Nebulae can take many forms, ranging from dark clouds that obscure starlight to bright, glowing regions where newly formed stars illuminate the surrounding gas. These clouds of gas and dust are not static; they are constantly shifting and changing under the influence of gravity. Over millions of years, nebulae collapse under their own gravity, compressing the gas and dust into clumps that heat up and begin to rotate. This process marks the beginning of star formation.

As the nebula collapses, the matter within it becomes increasingly concentrated, causing the temperature to rise significantly. The immense pressure leads to particles colliding at higher velocities, and the gas begins to heat up. As the temperature in the center of the cloud climbs to millions of degrees, a protostar begins to form. A protostar is essentially the early stage of a star, still in the process of gathering mass and energy before it begins nuclear fusion.

To form a fully-fledged star, a certain amount of mass is required. The minimum mass needed to trigger nuclear fusion is about 13 times the mass of Jupiter. This is the threshold for a body to begin fusing hydrogen into helium. Once this fusion process starts, a star is born.

The Birth of a Star

As the protostar heats up and pressure builds, hydrogen atoms in the core begin to fuse into helium through a process called nuclear fusion. This process releases vast amounts of energy in the form of light and heat, which pushes against the gravitational collapse of the star. For a star to remain stable and prevent itself from collapsing, it must maintain a delicate balance. The gravitational force from trillions of particles pulls inward so intensely that hydrogen fuses into helium, releasing energy. This energy attempts to escape, exerting an outward force that counters the inward gravitational pull. As long as these forces are balanced, the star remains stable for an extended period. This balance between the outward force of radiation and the inward pull of gravity is what keeps the star stable. For a star to remain in equilibrium and prevent collapsing under its own weight, the energy produced by fusion must match the gravitational pull trying to compress the star further.

At this stage, the star is referred to as a main-sequence star. It remains stable for the majority of its life, shining with a steady output of energy. Most stars, like our Sun, stay in this phase for billions of years, burning hydrogen in their cores and converting it into helium. The star can appear red, yellow, or even blue, depending on its size and temperature. Our Sun, for example, is a yellow main-sequence star.

The Red Giant Phase

As a star ages, it eventually exhausts the hydrogen in its core. Without hydrogen to fuse, the core contracts under gravity, causing the temperature to rise. This rise in temperature causes the outer layers of the star to expand, and the star becomes a red giant. The core becomes extremely hot and starts fusing helium into heavier elements, such as carbon and oxygen. The outer layers of the star cool and turn red, which is why these stars are called red giants.

During this phase, the star can expand significantly, sometimes up to 100 times its original size. This red giant phase lasts only a relatively short period in a star's life, typically a few hundred million years. As the helium in the core is consumed, the core contracts further, and the outer layers are ejected into space, forming a planetary nebula. This nebula is composed of the outer layers of the star that have been expelled, and over time, it disperses into space.

The Fate of a Star

The fate of a star largely depends on its mass. For medium-sized stars, like our Sun, the end of the red giant phase marks the transition into the next stages:

1. White Dwarf: Once a medium-sized star sheds its outer layers, the remaining core becomes a white dwarf. A white dwarf is a dense, hot remnant of the star, primarily composed of carbon and oxygen. It no longer undergoes fusion reactions but shines due to residual heat. White dwarfs are incredibly small, often no larger than Earth, yet they are extremely dense; an object the size of Earth can have a mass similar to that of the Sun. Over billions of years, the white dwarf will slowly cool and fade.

2. Black Dwarf: As a white dwarf cools, it eventually stops emitting light and becomes a black dwarf. A black dwarf is essentially a dead star, a cold, dark remnant that no longer radiates heat or light. However, this process takes trillions of years, far exceeding the current age of the universe. To date, no black dwarfs have been observed, as the universe is not old enough for them to have formed

The Death of Massive Stars

Massive stars, those with more than eight times the mass of the Sun, follow a much more dramatic path. When these stars exhaust their fuel, their cores become extremely dense and hot, leading to catastrophic changes in their structure and lifecycles.

Siddhi Srivastava
Bsc (h) Physics
3rd year

Wormholes: The Cosmic Shortcuts

Suppose the possibility of traveling from one end of the universe to the other in just a few seconds. While this concept may initially seem like the realm of science fiction, it is grounded in a respected theoretical framework known as wormholes.
Wormholes are a well known feature of science fiction as they allow faster-than-light interstellar travel within human timescales.

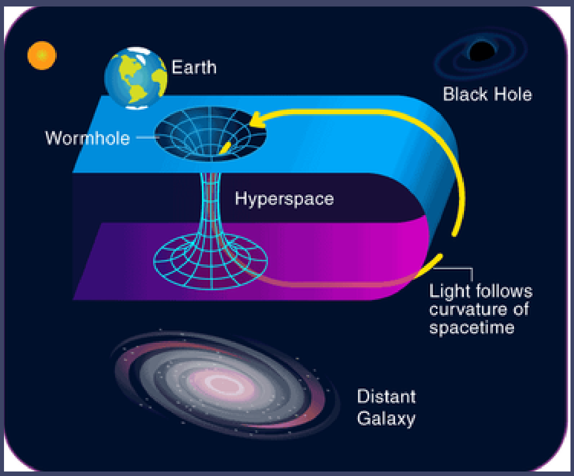
What are Wormholes?

A wormhole is a hypothetical tunnel that connects two distant points in space, functioning somewhat like a cosmic subway. This idea is supported by various theories of gravity, including the well-regarded principles of Einstein's general relativity, suggesting that wormholes could facilitate rapid movement of matter and energy.

https://cdn.mos.cms.futurecdn.net/iDAKYedZgsvhopan4bxj5W-650-80.jpg.webp

How Do Wormholes Work?

In theory, a wormhole consists of two openings that are linked across vast distances. When an object enters one mouth, it could emerge almost instantaneously from the other. To maintain the integrity of this tunnel, stabilization with exotic matter that possesses negative energy density would be necessary.



https://cdn1.byjus.com/wp-content/uploads/2022/02/wormhole-structure.png

The Possibilities

The potential of wormholes to enable faster-than-light travel is intriguing and could significantly change the landscape of interstellar exploration by reducing travel times. Such advancements would ideally broaden our horizons in understanding the universe.

The Challenges

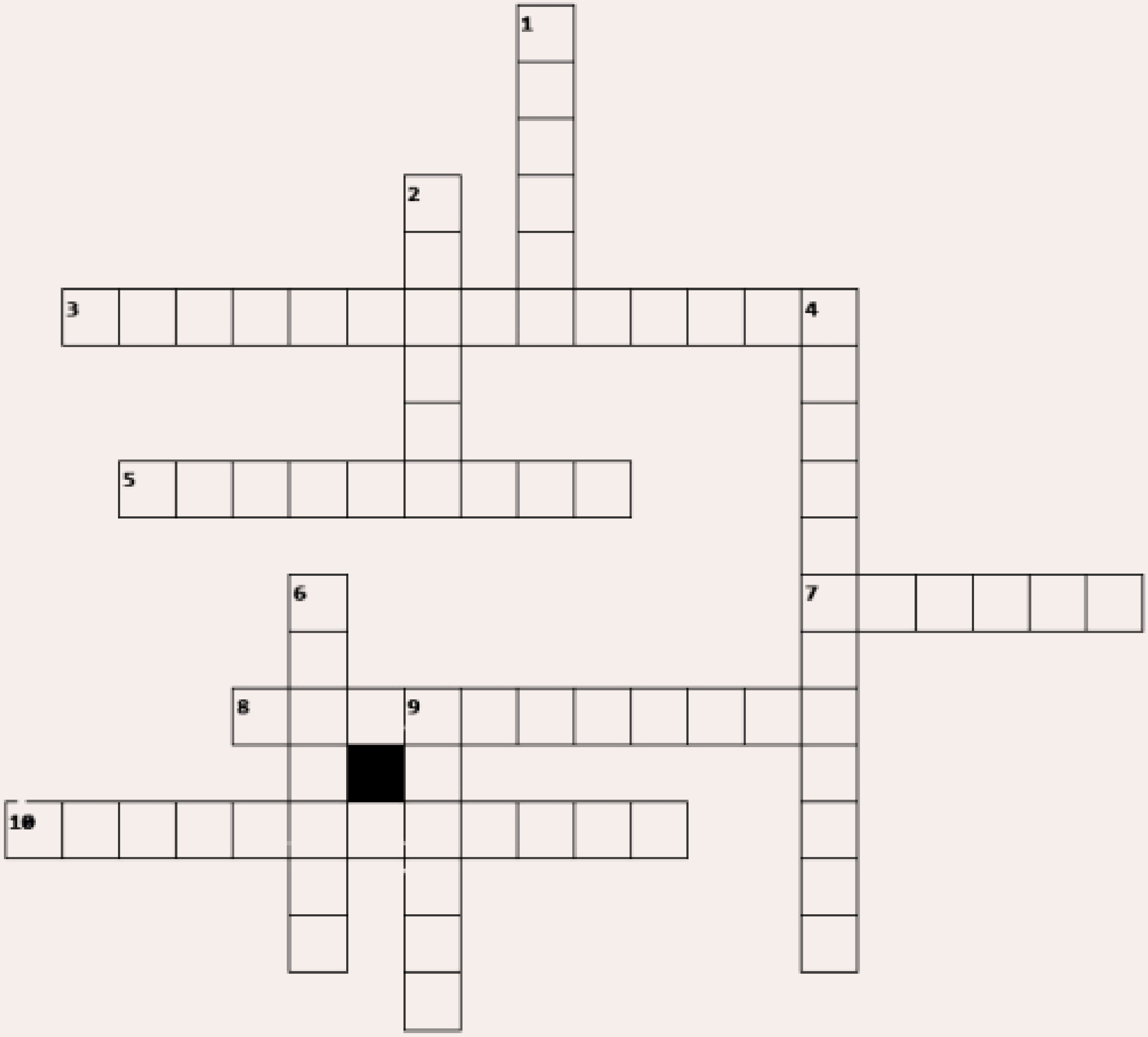
While the excitement surrounding wormholes is palpable, it's essential to recognize that they currently exist only in the theoretical realm. Many scientists express valid concerns regarding their stability and feasibility. Furthermore, the technology required to construct and navigate such phenomena is not yet within our reach.

Conclusion

Wormholes represent a fascinating possibility that could enrich our understanding of the universe. As ongoing research sheds light on the complexities of the cosmos, we may yet uncover remarkable insights that could lead us to new discoveries.

Tamanna
22567025
3rd year
Bsc(H) Physics

CROSSWORD



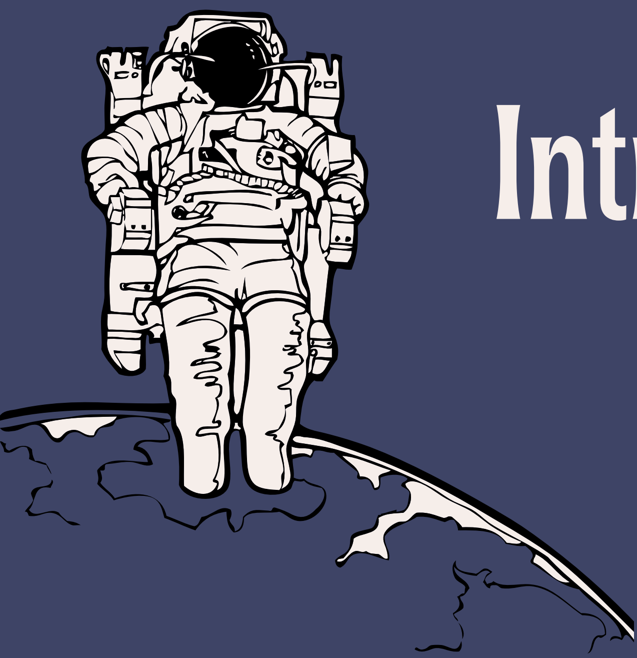
Across

3.physics that deals with heat and temperature
5.physics which deals with motion and its causes
7.physics that deals with light, colour and vision
8.the outward force from center of rotation objects
10.a physicist that plans, designs and performsexperiments

Down

1.this phenomenon powers the sun
2. classification of physics after 1900
4. c in E=mc^2
6. type of relativity that deals with very fast objects
9.it describes a phenomenon

Introduction to Space Explorations



Space exploration has fascinated humanity for centuries, pushing the boundaries of human ingenuity and imagination. It began as a dream of reaching beyond our planet to understand the mysteries of the cosmos. Over the decades, space exploration has evolved from theoretical concepts into groundbreaking achievements, resulting in numerous milestones that have forever altered our understanding of the universe and our place within it.

History

The journey of space exploration can be traced back to the mid-20th century when the space race between the United States and the Soviet Union defined the early years of the space age. The Soviet Union's launch of Sputnik 1 in 1957 marked the first artificial satellite to orbit Earth, signaling the beginning of the space race. This was followed by Yuri Gagarin's historic flight in 1961, making him the first human in space. The United States responded with NASA's Apollo program, culminating in Apollo 11's Moon landing in 1969, where Neil Armstrong became the first human to walk on the lunar surface.

The following decades saw numerous space probes and missions to explore planets, asteroids, and the outer reaches of our solar system. NASA's Voyager probes, launched in the 1970s, provided humanity with the first close-up images of Jupiter, Saturn, and their moons, ultimately traveling beyond the solar system. The 1990s introduced the Hubble Space Telescope, which revolutionized our understanding of distant galaxies, black holes, and the formation of stars. Meanwhile, the International Space Station (ISS), which began construction in 1998, has served as a multinational scientific laboratory in orbit, hosting astronauts and cosmonauts from around the world.

Major Milestones in Space Exploration

The Moon Landing (1969):

The Apollo 11 mission, led by astronauts Neil Armstrong, Buzz Aldrin, and Michael Collins, achieved the monumental goal of landing humans on the Moon. Armstrong's famous words, "That's one small step for man, one giant leap for mankind," symbolized not only a technological achievement but also a cultural moment that united humanity in its pursuit of the stars.

Mars Rovers:

In 1997, NASA's Sojourner rover landed on Mars as part of the Mars Pathfinder mission, marking the first successful rover deployment. Since then, several rovers have explored Mars, including Spirit and Opportunity, and more recently, Curiosity (2012) and Perseverance (2021). These rovers have provided invaluable information about the Martian surface, atmosphere, and its potential for past life.

The International Space Station (ISS):

Since 1998, the ISS has been a beacon of international cooperation in space exploration. This orbital research laboratory, which involves astronauts from NASA, Russia, Japan, the European Space Agency (ESA), and Canada, serves as a platform for scientific experiments in microgravity and helps advance our understanding of living and surviving in space long-term.

Future Goals of Space Exploration

As we look to the future, space exploration continues to evolve, with ambitious goals that will shape humanity's journey into the cosmos.

Mars Colonization:

One of the most ambitious goals of space exploration is to establish a human presence on Mars. NASA, along with private companies like SpaceX, has outlined plans for sending humans to the Red Planet. The Artemis Program, launched by NASA, aims to return humans to the Moon in preparation for future missions to Mars, with the long-term vision of creating a sustainable human presence there, potentially paving the way for colonization.

Artemis Missions:

The Artemis Program aims to return astronauts to the Moon by 2025 and is pivotal for advancing space exploration. Its ultimate goal is to establish a sustainable human presence on the Moon by the late 2020s, using it as a stepping stone for future exploration of Mars. Artemis I, an uncrewed mission to test the Space Launch System (SLS) and Orion spacecraft, is an important first step in this new era of lunar exploration.

Exploration Beyond Our Solar System:

Missions such as NASA's James Webb Space Telescope, launched in 2021, will revolutionize our understanding of distant planets, galaxies, and the origins of the universe. Scientists are increasingly focused on the search for habitable exoplanets within the habitable zones of other stars, hoping that one day we may discover life beyond Earth.

The Vastness of Space

Space is almost incomprehensibly vast, stretching far beyond what the human eye can see. The universe contains billions of galaxies, each hosting billions of stars and potentially even more planets, many of which could harbor life. Understanding the scale of the universe is essential for grasping how small Earth is in the grand scheme of things and recognizing how much more is yet to be explored. The universe is mind-boggling in its size. It is so enormous that it becomes difficult to conceptualize its full extent. The observable universe, the part we can see and measure, is just a fraction of the whole, reminding us of the vastness that remains to be discovered.

Shweta
Bsc (h) Physics
3rd year

Prof. Sudha Gulati:

A Life of Teaching, Research and Inspiration

Interviewer: Ishu Bhadana **B.Sc (H) Physics III Year**

1. Can you share a significant struggle from your early life that shaped the person you are today?

I passed my MSc in Physics in 1993, immediately after passing I got the opportunity to work as an assistant professor at Kalindi College and simultaneously was also doing research in the Department of Physics, University of Delhi. So I have to maintain balance between the two roles in my life one of a Teacher who is teaching the students and the second as a researcher who is leading a student's life. Both the experiences played a significant in shaping my personality. It has sharpened my skills in logical analysis. I have to take out time for both the roles and it was quite challenging to make a balance between the two.

2. Did you face any resistance or challenges from family or society when choosing a career in physics?

I was fortunate to have a very supportive family who always encouraged me to follow my passion. My father & uncle who were in Delhi University and mother a very religious lady always encouraged, supported and motivated me to study since my childhood. I completed my graduation from Miranda House and MSc from University of Delhi.

3. Was there a moment when you doubted your path in academia or research? How did you overcome it?

Yes, there was moment when I doubted my path in research during PhD. Though I was doing a lot of hard work in Research lab, but for few years in the beginning I was not getting success in my efforts. But I was able to overcome this challenge by persistent, continuous hard work and determination with positive attitude. I always had in my mind that I have to keep on troubleshooting problems arising during research and there is no scope for Failure and if you are determined then "Nothing is IMPOSSIBLE". As I progressed, I can see some light ahead and this motivated me and I followed the light.

4. What sacrifices did you have to make in your personal life to achieve success in your career?
I have lived a very disciplined life. I got married and my son was also born during my PhD. However I tried to keep a balance between my responsibilities and roles at home as a mother, in college as a teacher, and researcher doing research for my career advancement. Although my daily schedule became quite hectic after marriage, I managed to navigate these challenges by keeping a balance and continuous support of my in-laws.
After completing my PhD, there was a period when I had to take a break from research, etc to fulfill my responsibilities as a mother, so I was deeply involved with my children and after both my children passed out of 12th class, I again restarted my research work. When I started research after about 20 years, then I decided to shift my focus to Nanomaterials which has a wide array of applications. It was a challenge for me to start research in this new area and for this I have to study a lot and to learn various software tools, master new characterization techniques, and learn deposition methods to reignite my work. This renewed focus enabled me to publish research papers in several reputed journals, and this helped me to be promoted to Professor of Physics in July 2024.

5. What were the biggest challenges you faced during your Ph.D. research, and how did you stay motivated?
After spending a few years in PhD. I was very much discouraged due to the politics between the supervisors in the department and started having this feeling that I would not be able to complete PhD due to the adverse circumstances.
With support & motivation from my family and my faith in God gave me a lot of courage & determination. Thus, I again gathered my courage and decided to keep on continuing my work irrespective of the problems faced everyday with the best of my efforts. I decided "Not to stop till my research work is over".

6. How do you handle failures or setbacks in research and teaching? Can you share a specific moment when things didnt go as planned?
Failures and setbacks are inevitable in research, and are part of the growth process. In research lot of patience is required, setbacks might come as confusing experimental observations which are difficult to explain, you have to repeat experiments with hit and trial. The key is to view these moments not as defeat but as learning opportunities to refine your work. My PhD was on gas sensor and it took around one year in the designing of set ups required for taking experimental observations as I have to optimise on the efficiency & accuracy of the set up with each experiment. I have to do many experiments to increase the value of sensitivity of gas sensor experimentally, and it took lot of time and tested my patience. I took in a positive way and studied in detail all the factors which affect sensitivity which led me to develop a theoretical model. My experience is that even when things don't go as planned, consistent and persistent effort inevitably leads to success.

7. **Do you practice any specific mental wellness techniques like meditation, exercise, or mindfulness?**
Yes, I have been practicing meditation since I was in school. My mother is very religious and I used to watch her doing meditation. She encouraged me to practice meditation. This long-standing commitment to meditation probably helps to stay grounded, strong faith in God, and maintain inner peace, even during difficult times.

8. **Have you ever felt guilty for prioritizing work over personal life, or vice versa? How do you deal with such emotions?**
Sometimes I have to prioritize work over personal life. But I have always tried to maintain a balance between personal life and my work, though though I am having very hectic schedule. I have been teaching for the last 30 years.

Every year I am able to complete syllabus in time and prioritize work over personal life so that students should not suffer.

9. How do you separate work stress from your personal life? Has it been difficult to maintain boundaries?
Separating work stress from personal life is tough, by maintaining a healthy balance makes a huge difference. I have a dedicated workspace for my academic studies, preparing for lectures and research work etc.
When I leave my workspace I shift the focus to personal time. I do meditation in my routine. This is very helpful to relax my mind and overcome stress.

10. Who or what has been your greatest emotional support system throughout your career?
My Uncle who was professor of Physics in Delhi University was my Mentor and Guruji. He used to clear my doubts in Physics when I was in school and college. It really helped to strengthen my basics in science. My parents were my emotional support and husband was motivational support throughout my career.

11. What advice would you give to students who struggle with quantum mechanics?
I always advise students to revise derivations by writing them out, as it reinforces understanding and retention not only for quantum mechanics but for any subject. I always encourage & motivate students to clear their doubts without any hesitation. I tell students to create a consolidated list of important equations in the class and recommend them to review them daily to memorize effortlessly. Additionally, practicing plenty of numerical problems helps solidify concepts, clear their doubts and build confidence.

12. Many young researchers struggle with stress, failure, and pressure. What advice would you give them?
According to my own experience, Research is a challenging journey, and researcher has to go through a lot of stress, failure, and pressure. **If** the researcher pursues their work with patience & determination, persistent hard work, and above all with a positive attitude, then they can overcome any challenge, ultimately leading to success.

13. How important is mental health in academia, and do you think institutions should provide more mental health support?
Mental health is indispensable in academia. There is a lot of pressure of research deadlines, teaching responsibilities, etc. which generate stress and anxiety. When mental well-being is neglected, it can stifle creativity, lower productivity, and even lead talented researchers to leave academia.
Institutions can play a vital role in supporting mental health by offering accessible psychologists, organizing stress management workshops, and providing mentoring programs. Beyond that, by creating healthier work environments — like promoting work-life balance, advising students to have realistic expectations, and encouraging regular breaks having extra-curricular activities— can make a significant difference.

14. If you could go back in time and talk to your younger self during a difficult phase, what would you say?
Believe in yourself, and always be positive no matter whatever are the challenges. Every challenge, every failure, and every moment of doubt is a driving force to discover new things in life, adding your experiences and sharpening your trouble shooting skills. Sometimes you might have negative thoughts, but persistent positive efforts will ultimately take you out of difficult times.

15. What role does emotional intelligence play in succeeding as a scientist and teacher?
I must say that before being a scientist or a teacher we are humans and to maintain the efficacy and functionality as a human, one of the aspects must include understanding emotions.
I understand where the question is stemming from that being scientist is seen as a profession in search for objective truth and many believe

that objectivity means leaving emotions at the door. But there is no such thing as an objective truth, there are only realities, and possibilities such as Heisenberg's uncertainty principle. In research, emotional intelligence helps in collaboration, and navigating the inevitable setbacks that come with exploring the unknown.
There is also an utmost need of understanding emotions as a teacher since the teacher involves interacting with students on daily basis. And if the teacher is not understanding the emotions of students, it can even potentially obstruct the process of learning.

16. What is your personal philosophy or mantra that helps you stay mentally strong?
I believe in Never leaving a task incomplete. I maintain a positive attitude and, whenever I encounter a hiccup, I pause to reflect, identify the issue, correct it, and move forward. Additionally, I rely on chanting to bolster my strength and resilience.

17. How do you define success by achievements, impact, or personal fulfilment?
Success, in my view, can be defined to be a combination of achievements, impact, and personal fulfilment—all of which are interwoven to produce a journey that has a purpose.

As a teacher, I consider my success to be reflected in my students' career achievements and the respect they show for the teacher. When my students excel professionally and recognize the value of the education they have received, then I consider that my work as an educator has made a meaningful impact.

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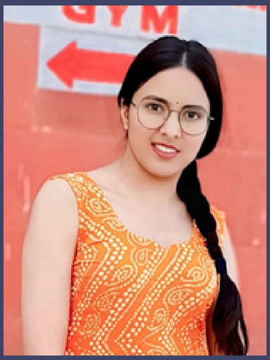

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