KARNATAKA PHYSICS ASSOCIATION (R.)

(Reg. No. DRB 2/SOR/210/2021-2022)

Website: karnatakaphysicsassociation.in

KPA NEWSLETTER – 6 **February 2025**

Editors

Prof. B. A. Kagali (Chief Editor)
Prof. Somashekar Sidiginamale
Prof. P. Nagaraju
Prof. S. P. Basavaraju
Prof. M. R. Nandan

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Editor's Note

This is the first issue of the newsletter for the year 2025.It contains several interesting articles- including modern topics like applications of AI, top quark production, quantization of gravity and the largest radio telescope being built – apart from three biographical articles. An obituary of Leon Cooper, the Nobel laureate who developed the microscopic theory of superconductivity along with Bardeen and Schrieffer, highlights his many achievements. An article about generative AI systems like ChatGPT tells us how it is different from other types of AI systems. A biographical sketch of J Robert oppenheimer, commonly regarded as the father of atomic bomb in USA, gives us details about his personality and contributions. Electric and magnetic fields are intertwined in Special Relativity. This is illustrated in a pedagogical article. Recently, top quarks were produced at CERN for the first time. An account of their production is given in a short news article. So much effort has been done to 'quantize' gravity. The next article throws some light on some recent thinking about the matter. High precision Radio astronomy is being used to probe the contents of the early universe. An article about the biggest radio telescope that is being built in an international collaboration is included in this issue for all to read. An article about the various 'external' parts of a typical airplane and how they function to control flight is described in simple terms for students and flight enthusiasts is available for all to read. Bibha Chowdhury was an eminent Indian woman cosmic ray physicist who, unfortunately, has not been recognized properly in the country so far. An article about her struggles and achievements finds a place here. Hans berger of Germany played an important role in the development of EEG and its use in medicine. An article about his life and contributions is included here. An article about supernovae – giant exploding stars – in Kannada giving a detailed account of their special properties is also included in this issue. A few well-written review articles (open-source type) penned by distinguished science journalists on topics of current interest have been included in this issue for the benefit of our members. Along with the above-mentioned articles, two regular features – activities of KPA members along with some photos and the Sunday webinars held during the past three months – are included for the information for one and all.

It is hoped that a greater number of articles from KPA members and others will be forthcoming in the next issue of the newsletter which is due in May 2025. Articles in Kannada are especially welcome since there is an urgent need to create higher educational content in Kannada as an important step forward towards self-reliance (atmanirbharata) in education and, more importantly, for truly effective teaching and learning of science in Karnataka!

KPA sincerely thanks Dr.Muktha B.Kagali for sparing her time to design this newsletter at short notice, free of charge.

Readers' comments and suggestions about the style, contents etc. of the newsletter are most welcome.

- **Chief Editor**

Leon Cooper Obituary

Georgina Ferry
Science Journalist

Nobel laureate who developed the theory of superconductivity

Leon Cooper, who died aged 94 (on Nov.19, 2024), helped to solve a problem that had stumped many of the greatest minds in twentieth-century physics. With his colleagues John Bardeen and Robert Schrieffer, he deciphered the dance of electrons that causes superconductivity, or the sudden drop in electrical resistance experienced by certain materials, such as mercury, when they reach temperatures only a few degrees above absolute zero. This phenomenon has since served to generate, for example, the very high magnetic fields needed to operate technology such as magnetic resonance imaging body scanners. The Bardeen–Cooper–Schrieffer (BCS) theory of superconductivity won them the Nobel Prize in Physics in 1972.

Leon Cooper

Having worked out one of the hardest problems in physics, Cooper turned his attention to neuroscience. With his graduate students Elie Bienenstock and Paul Munro, he developed a model — inevitably dubbed the Bienenstock–Cooper–Munro (BCM) theory to mirror the BCS theory — of changes in the strength of the neuronal connections in the brain as individuals learn.

His pioneering theoretical work on neural networks places him in the company of other physicists such as John Hopfield and Geoffrey Hinton — winners of the 2024 Nobel Prize in Physics who developed algorithms that could represent the process of learning in a model of a very small volume of brain tissue.

Cooper (originally Kupchik) was born in New York City, the son of Jewish immigrants from Belarus and Poland. After his mother died, he and his sister spent part of their childhood in care. In 1947, he graduated from the Bronx High School of Science, which has produced six other Nobel laureates in physics. He then studied physics at Columbia University, New York City, completing a PhD in 1954.

Why superconductor research is in a 'golden age' — despite controversy He joined the Institute of Advanced Study in Princeton, New Jersey, for a year, before Bardeen recruited him to the University of Illinois at Champaign–Urbana, to work together on problems of condensed-matter theory, specifically superconductivity. "The long and very imposing list of physicists (among them [Niels] Bohr, [Werner] Heisenberg and [Richard] Feynman) who had tried or were trying their hand at superconductivity should have given me pause," recalled Cooper in a later memoir. Feynman had even said that anyone trying to tackle superconductivity would soon discover that they were "too stupid to solve the problem".

Superconductivity was first observed in 1911, but by the mid-1950s it was still unknown how electrons could flow seemingly without limit in supercooled mercury. Some suggested that new physics — an undiscovered kind of particle, for example — might be needed to account for the phenomenon. Working for more than a year with every theoretical tool at his disposal, Cooper proposed that faint vibrations in lattices of atoms at low temperatures prompted electrons to pair up instead of repelling one another. All of these 'Cooper pairs' could in turn operate as a single entity and pass through the lattice unopposed.

Mathematical analysis by Schrieffer supported the theory, which Bardeen refined. Their paper caused a sensation (J. Bardeen *et al. Phys. Rev.* **108**, 1175; 1957); it was subsequently confirmed by experiment. The same phenomenon also underlies the performance of more recently discovered 'high-temperature superconductors', which reach a resistance-free state at up to 100 degrees above absolute zero. "The great thing that Bardeen, Cooper and Schrieffer showed was that no new particles or forces had to be introduced to understand superconductivity," wrote Steven Weinberg, a theoretical physicist who won the Nobel Prize in Physics in 1979.

How would room-temperature superconductors change science?

In 1958, Cooper moved to Brown University in Providence, Rhode Island, where he remained for the rest of his working life. In 1974, he founded the Institute for Brain and Neural Systems there, recruiting a team to research the connectivity underlying cognitive function.

The group built on the work of pioneers such as brain researchers Warren McCulloch and Walter Pitts of the University of Illinois at Chicago, who had published a mathematical model of a neural network in 1943 (W. S. McCulloch and W. Pitts, *Bull. Math. Biophys.* **5**, 115–133; 1943), and of the Canadian psychologist Donald Hebb, whose 1949 book *The Organization of Behavior* proposed that, if neurons repeatedly fire — that is, send electrical signals — to the body and brain at the same time, the synapses between them become stronger.

The BCM theory, published in 1982, addressed how specific cells in the visual cortex become selective for certain stimuli, such as an edge at a particular angle, depending on previous visual experience. It proposed that, the more often incoming signals activated a neuron, the higher the threshold for its activation would become, and vice-versa. This sliding threshold has the effect of stabilizing the responsiveness of the neuron, making it either more or less active. Cooper's goal was to model how living brains work, and the BCM theory has stood the test of time. It has also played a part in the development of machine learning. Cooper and his collaborators went on to apply insights from machine learning to many other fields, such as sonar detection.

Although he formally retired in 2014, Cooper never lost his curiosity. That year, he published a collection of essays, *Science and Human Experience*, based on his lively interest in physics, neuroscience, philosophy and how these fields interacted with each other. He argued that science emerged from a uniquely human desire to explain the world that surrounds us, and that imagination was a crucial part of the process. “Our imagination is marvelously free,” he wrote, “capable of any juxtaposition, unbounded by logic or experience.”

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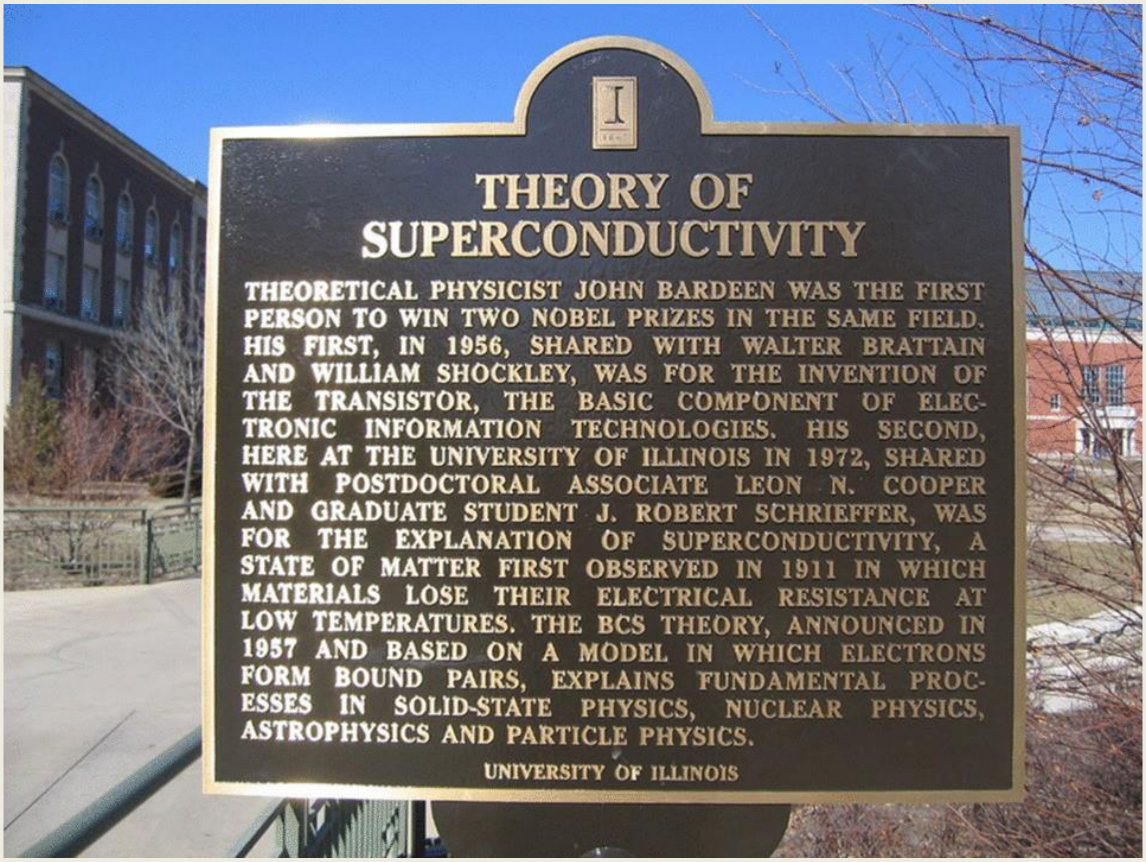

How Generative AI Systems Like ChatGPT Work: What Sets Them Apart from Other AI

Adam Zewe , MIT News

A quick scan of the headlines makes it seem like generative artificial intelligence is everywhere these days. In fact, some of those headlines may actually have been written by generative AI, like OpenAI's ChatGPT, a chatbot that has demonstrated an uncanny ability to produce text that seems to have been written by a human.

But what do people really mean when they say "generative AI?"

Before the generative AI boom of the past few years, when people talked about AI, typically they were talking about machine-learning models that can learn to make a prediction based on data. For instance, such models are trained, using millions of examples, to predict whether a certain X-ray shows signs of a tumor or if a particular borrower is likely to default on a loan.

Generative AI can be thought of as a machine-learning model that is trained to create new data, rather than making a prediction about a specific dataset. A generative AI system is one that learns to generate more objects that look like the data it was trained on.

"When it comes to the actual machinery underlying generative AI and other types of AI, the distinctions can be a little bit blurry. Oftentimes, the same algorithms can be used for both," says Phillip Isola, an associate professor of electrical engineering and computer science at MIT, and a member of the Computer Science and Artificial Intelligence Laboratory (CSAIL).

And despite the hype that came with the release of ChatGPT and its counterparts, the technology itself isn't brand new. These powerful machine-learning models draw on research and computational advances that go back more than 50 years.

An increase in complexity

An early example of generative AI is a much simpler model known as a Markov chain. The technique is named for Andrey Markov, a Russian mathematician who in 1906 introduced this statistical method to model the behavior of random processes.

In machine learning, Markov models have long been used for next-word prediction tasks, like the auto compete function in an email program.

In text prediction, a Markov model generates the next word in a sentence by looking at the previous word or a few previous words. But because these simple models can only look back that far, they aren't good at generating plausible text, says Tommi Jaakkola, the Thomas Siebel Professor of Electrical Engineering and Computer Science at MIT, who is also a member of CSAIL and the Institute for Data, Systems, and Society (IDSS).

"We were generating things way before the last decade, but the major distinction here is in terms of the complexity of objects we can generate and the scale at which we can train these models," he explains.

Just a few years ago, researchers tended to focus on finding a machine-learning algorithm that makes the best use of a specific dataset. But that focus has shifted a bit, and many researchers are now using larger datasets, perhaps with hundreds of millions or even billions of data points, to train models that can achieve impressive results.

The base models underlying ChatGPT and similar systems work in much the same way as a Markov model. But one big difference is that ChatGPT is far larger and more complex, with billions of parameters. And it has been trained on an enormous amount of data — in this case, much of the publicly available text on the internet.

In this huge corpus of text, words and sentences appear in sequences with certain dependencies. This recurrence helps the model understand how to cut text into statistical chunks that have some predictability. It learns the patterns of these blocks of text and uses this knowledge to propose what might come next.

More powerful architectures

While bigger datasets are one catalyst that led to the generative AI boom, a variety of major research advances also led to more complex deep-learning architectures.

In 2014, a machine-learning architecture known as a generative adversarial network (GAN) was proposed by researchers at the University of Montreal. GANs use two models that work in tandem: One learns to generate a target output (like an image) and the other learns to discriminate true data from the generator's output. The generator tries to fool the discriminator, and in the process learns to make more realistic outputs. The image generator Style GAN is based on these types of models.

Diffusion models were introduced a year later by researchers at Stanford University and the University of California at Berkeley. By iteratively refining their output, these models learn to generate new data samples that resemble samples in a training dataset, and have been used to create realistic-looking images. A diffusion model is at the heart of the text-to-image generation system Stable Diffusion.

In 2017, researchers at Google introduced the transformer architecture, which has been used to develop large language models, like those that power ChatGPT. In natural language processing, a transformer encodes each word in a corpus of text as a token and then generates an attention map, which captures each token's relationships with all other tokens. This attention map helps the transformer understand context when it generates new text.

These are only a few of many approaches that can be used for generative AI.

A range of applications

What all of these approaches have in common is that they convert inputs into a set of tokens, which are numerical representations of chunks of data. As long as your data can be converted into this standard, token format, then in theory, you could apply these methods to generate new data that look similar.

"Your mileage might vary, depending on how noisy your data are and how difficult the signal is to extract, but it is really getting closer to the way a general-purpose CPU can take in any kind of data and start processing it in a unified way," Isola says.

This opens up a huge array of applications for generative AI.

For instance, Isola's group is using generative AI to create synthetic image data that could be used to train another intelligent system, such as by teaching a computer vision model how to recognize objects.

Jaakkola's group is using generative AI to design novel protein structures or valid crystal structures that specify new materials.

The same way a generative model learns the dependencies of language, if it's shown crystal structures instead, it can learn the relationships that make structures stable and realizable, he explains.

But while generative models can achieve incredible results, they aren't the best choice for all types of data. For tasks that involve making predictions on structured data, like the tabular data in a spreadsheet, generative AI models tend to be outperformed by traditional machine-learning methods, says Devavrat Shah, the Andrew and Erna Viterbi Professor in Electrical Engineering and Computer Science at MIT and a member of IDSS and of the Laboratory for Information and Decision Systems.

"The highest value they have, in my mind, is to become this terrific interface to machines that are human friendly. Previously, humans had to talk to machines in the language of machines to make things happen. Now, this interface has figured out how to talk to both humans and machines," says Shah.

Raising red flags

Generative AI chatbots are now being used in call centers to field questions from human customers, but this application underscores one potential red flag of implementing these models — worker displacement.

In addition, generative AI can inherit and proliferate biases that exist in training data, or amplify hate speech and false statements. The models have the capacity to plagiarize, and can generate content that looks like it was produced by a specific human creator, raising potential copyright issues.

On the other side, Shah proposes that generative AI could empower artists, who could use generative tools to help them make creative content they might not otherwise have the means to produce.

In the future, he sees generative AI changing the economics in many disciplines.

One promising future direction Isola sees for generative AI is its use for fabrication. Instead of having a model make an image of a chair, perhaps it could generate a plan for a chair that could be produced.

He also sees future uses for generative AI systems in developing more generally intelligent AI agents."There are differences in how these models work and how we think the human brain works, but I think there are also similarities. We have the ability to think and dream in our heads, to come up with interesting ideas or plans, and I think generative AI is one of the tools that will empower agents to do that, as well," Isola says.

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The Master Storyteller AI

In a vast library of knowledge, a curious researcher meets ChatGPT, a brilliant storyteller unlike traditional AI.

"How do you know so much?" the researcher asks.

"I don't just retrieve answers—I generate them," ChatGPT explains. "Unlike task-specific AI, I'm built on a large language model (LLM), allowing me to create, analyze, and adapt across domains."

"How do you learn?"

"Through transformer architecture—thousands of attention mechanisms help me understand context, relationships, and nuances like humor or emotion."

"So, are you perfect?"

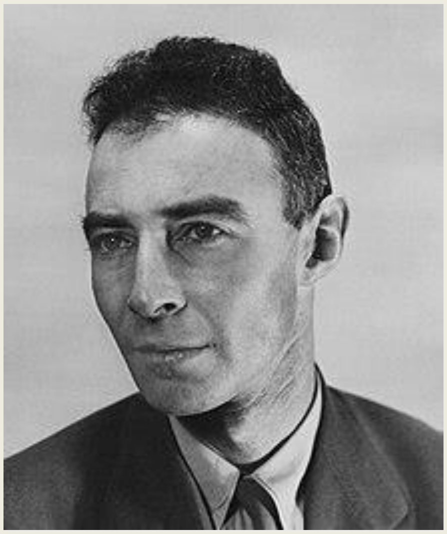
The AI chuckles. "No—I predict words based on probabilities, not deep reasoning. But I continuously learn, improving with each interaction."

The researcher, fascinated, leaves with a newfound appreciation—ChatGPT is more than a database; it's a creator, conversationalist, and powerful tool shaping the future.

This anecdote is an original creative explanation based on widely known principles of generative AI, deep learning, and transformer-based models.

Julius Robert Oppenheimer -"Father" of the Atomic Bomb

Dr. Rudraswamy
Former Professor of Physics, Bangalore University



J Robert oppenheimer

After helping invent the atomic bomb, the physicist , J. Robert Oppenheimer spent decades thinking about how to preserve civilization from technological dangers, offering crucial lessons for the age of Artifical Intelligence .

From the moment the atomic bomb was dropped on Hiroshima in August 1945 until his death in 1967, J. Robert Oppenheimer was perhaps the most recognizable physicist on the planet.In 1942, Oppenheimer was appointed to the Manhattan Project, code name for the project formed to develop an atomic bomb.He went on to serve for almost 20 years as Director of the Institute for Advanced Study (IAS) in Princeton, New Jersey (NJ), USA , home to some of the world's leading scientists, including **Albert Einstein.** In the popular imagination, Einstein represented human genius to uncover the secrets of the cosmos , whereas Oppenheimer played a grimmer role, standing for the dangers of advancing science**.**

Much of his subsequent career would be spent advising humanity, how, not to be destroyed by the powers of the atom he had conquered. However , the advice was not always well received: The Atomic Energy Commission (AEC) , USA stripped him of his security clearance in 1954, in part because of his pleads for arms control. (AEC posthumously reversed that decision last year).Much has been written about his leadership of the Los Alamos National Laboratory, his political affiliations and post war military/security compliications and his early death from cancer. For another key period of his life, from 1947–66, Oppenheimer served as the Director of IAS, which is the longest tenure for any Director thus far. Oppenheimer's legacy at IAS is keenly felt today. His focus on intellectual freedom and quality of approach highlighted by the active role that he took in bringing together scholars from diverse disciplines to address important questions of the day, continues to be typical example in IAS scholarship.

Born on April 22, 1904, in New York City, Julius Robert Oppenheimer grew up in a Manhattan apartment attractive with paintings by van Gogh, Cézanne, and Gauguin. His f father, Julius Oppenheimer, was a German immigrant who worked in his family's textile importing business. His mother, Ella Friedman, was a painter whose family had been in New York for generations. His younger brother, Frank, would also become a physicist.

In 1921, Oppenheimer graduated from the Ethical Culture School of New York at the top of his class. At Harvard, Oppenheimer studied mathematics , science, philosophy , Eastern religion, French and English literature. He was admitted to graduate in physics in his first year as an undergraduate . During a course on thermodynamics taught by Percy Bridgman, Higgins University Professor of Physics at Harvard, Oppenheimer was introduced to experimental physics, which quickly caught his attention. He graduated in 1925 and afterwards went to Cambridge University's Cavendish Laboratory as research assistant to **J. J. Thomson**. Uninspired by routine laboratory work, he went to the University of Göttingen, in Germany, to study quantum physics. Oppenheimer met and studied with some of the day's most prominent figures, including **Max Born** and **Niels Bohr**. In 1927, Oppenheimer received his **doctorate**, and in the same year, worked with Born on the structure of molecules, producing the **Born-Oppenheimer Approximation**.

Subsequently, he traveled from one prominent center of physics to another: Harvard, California Institute of Technology, Leyden and Zürich. In 1929, he received offers to teach at Caltech and the University of California at Berkeley. Accepting both, he attracted his own circle of brilliant young physics students.

Oppenheimer in 1947 at the Shelter Island conference where theoretical physicists gathered to discuss the state of their field in the aftermath of World War II. From left to right, standing, are: W. Lamb, K.K. Darrow, Victor Weisskopf, George E. Uhlenbeck, Robert E. Marshak, Julian Schwinger, and David Bohm. From left to right, seated are: J. Robert Oppenheimer (holding pipe), Abraham Pais, Richard P. Feynman (seated, with pen in hand), and Herman Feshbach

His lectures were a great experience, for experimental as well as theoretical physicists, commented the late physicist **Hans Bethe** (1906–2005), who would later work with Oppenheimer at Los Alamos. "He was a man who obviously understood all the deep secrets of quantum mechanics, and yet made it clear that the most important questions were unanswered. His deep involvement gave his research students the same sense of challenge. He never gave his students the easy and superficial answers but trained them to appreciate and work on the deep problems."

When his father died in 1937, Oppenheimer became a wealthy man. In 1940, he married Katherine (Kitty) Puening Harrison, a biologist and divorcee whose second husband had been killed during the Spanish Civil War.

The couple had two children, Peter and Katherine. World War II interrupted the work and lives of most American physicists. In 1942, Oppenheimer was appointed to the

Group photograph taken at a conference held on March 19, 1949, in honor of Albert Einstein's 70th birthday. Pictured from left to right are: Howard Percy Robertson, Eugene Paul Wigner, Hermann Weyl, Kurt Gödel, I.I. Rabi, Albert Einstein, Rudolf Walther Ladenburg, J. Robert Oppenheimer, and Gerald Maurice Clemence.

Manhattan Project, the code name for the project formed to develop an atomic bomb.The project involved several laboratories in secret locations across the country, including the University of Chicago; Oak Ridge, Tennessee; and Los Alamos, New Mexico. Oppenheimer oversaw the construction of the Los Alamos laboratory, where he gathered the best minds in physics to work on the problem of creating an atomic bomb. Because of his leadership in this project, he is often referred to as the "**father" of the atomic bomb**.

Robert Oppenheimer (right) with John von Neumann in front of the Electronic Computer Project's ENIAC machine, ca. 1952.

When the war ended, the USA government set up the AEC to replace the Manhattan Project. The AEC was overseeing all atomic research and development in the United States. As Chairman of the General Advisory Committee, Oppenheimer **opposed** the development of the **hydrogen bomb**. Known as the **"Super Bomb,"** which was a thousand times more powerful than the atomic bomb. In the context of the Cold War, when the United States and the Soviet Union struggled for power, Oppenheimer's attitude was controversial. In the 1950s, while Oppenheimer was Director of the IAS, anti-Communist hysteria was sweeping through Washington, D.C., led by the conservative Senator Joseph McCarthy of Wisconsin. McCarthy and anti-Communist zealous people devoted themselves to rooting out Communist secret agents from every walk of American life. Oppenheimer was subjected to a security investigation. In 1953, he was denied security clearance and lost his position with the AEC. Doors that had formerly been open to him were closed. "Oppenheimer took the outcome of the security hearing very quietly but he was a changed person; much of his previous spirit and liveliness had left him" recalled Bethe. He delivered the Reith Lectures on the BBC in 1953, and these were published under the title "Science and the Common Understanding." In April 1962, the U.S.

Government made amends for the treatment Oppenheimer suffered during denied security clearance , when President Kennedy invited him to a White House dinner of Nobel Prize winners. In 1963, President Johnson awarded **Oppenheime**r the highest honor given by the AEC, the **Fermi Award**.

Oppenheimer died of throat cancer on February 18, 1967. After the successful test of the " device " as the **first atomic bomb** was called, he is said to have quoted the **Bhagavad Gita**: "**Now I am become death, the destroyer of worlds**."

Oppenheimer's fascination with the Bhagavad Gita is well-documented. It is said that he carried a copy of the Gita with him and frequently referred to its verses during thought of the day. In particular, Oppenheimer found resonance with the Gita's teachings on the interplay between light and darkness, creation and destruction, and the moral dilemmas faced by individuals in positions of power. Oppenheimer's journey and his encounter with the Bhagavad Gita serve as a reminder that human understanding is not confined to one domain alone. Here are a few quotes from the Bhagavad Gita that J. Robert Oppenheimer found particularly inspiring:

• "Now I become Death, the destroyer of worlds." (Chapter 11, Verse 32)
• "You have the right to perform your prescribed duty, but you are not entitled to the fruits of your actions." (Chapter 2, Verse 47)
• "The wise see that there is action amid inaction and inaction amid action." (Chapter 4, Verse 18)
• "The soul is neither born and nor does it die." (Chapter 2, Verse 20)
• "Among weapons, I am the thunderbolt." (Chapter 11, Verse 23)

These quotes demonstrate Oppenheimer's deep appreciation for the philosophical and spiritual teachings of the Bhagavad Gita, which helped shape his worldview and moral thinking. The fascinating connection between Oppenheimer and the Bhagavad Gita bridges the gap between science and philosophy, revealing the inter-connectedness of human pursuits in the quest for knowledge and wisdom.

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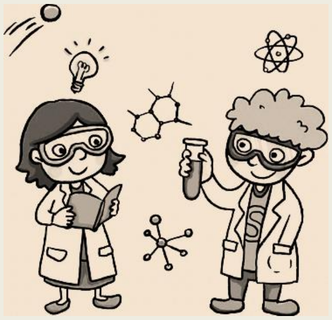


Magnetic Field and Special Theory of Relativity

Prof. K M Raghavendran
Physics dept., MES College, Bengaluru

Introduction: It's well-known that magnetic fields arise from two primary sources: moving electric charges and the intrinsic magnetic moments of elementary particles, a quantum property linked to spin. Special Theory of Relativity (STR or SR for short) a foundation of modern physics, describes the relationship between space and time for observers in inertial reference frames. This article explores the interesting connection between SR and magnetic fields generated by moving charges.

By the late 19th century, the relationship between electricity and magnetism was well-understood, supported by a robust mathematical framework. James Clerk Maxwell's theory of electromagnetism, formulated in 1875 unified these phenomena. In 1905, Albert Einstein's groundbreaking paper, ' Zur Elektrodynamik bewegter Körper or "On the Electrodynamics of Moving Bodies," laid the foundation for STR. It was motivated by the inconsistencies observed in the concept of absolute motion and the incompatibility of Maxwell's equations with Newtonian/Classical mechanics. Einstein proposed a radical new perspective.

STR transforms classical mechanics, particularly for objects moving at relativistic speeds (speeds that are close to the speed of light). A key feature is the replacement of Galilean transformations with Lorentz transformations, which accurately describes the relationship between different inertial reference frames .Furthermore, STR challenges our intuitive notions of space and time as separate entities, merging them into a single entity known as ***spacetime***. One of its most counterintuitive consequences, length contraction, is particularly relevant to our discussion.

Further, STR reveals a deep connection between electricity and magnetism by demonstrating that they are not separate phenomena but rather two aspects of a unified entity called the electromagnetic field. This connection arises from the way SR transforms physical laws between different inertial frames of reference. The electric (**E**) and magnetic (**B**) fields transform into each other when observed from different inertial frames moving relative to one another. These transformations depend on the relative velocity of the reference frames and the orientation of the fields. For instance ,if a purely electric field is observed in one frame, an observer in a frame moving relative to the first with a uniform velocity might detect both an electric field and a magnetic field. Similarly, a moving charge creates a magnetic field in addition to the electric field, depending on the observer's frame of reference.

Generally, when we introduce STR there is an impression created in the minds of the students that the effect of STR comes into play only when the relative speed of two objects is a considerable fraction of the speed of light (c). Surprisingly this is not the case. In fact, relativistic length contraction, along with Coulomb's law, accounts quantitatively for the force on a charged particle as it moves relative to a current-carrying wire. This force, which in the reference frame of the wire we call "magnetic force", is measurable and important even at relative speeds on the order of 10^{-12}c. This article explores the relation between magnetism and special relativity.

A Gedenken experiment based on STR: Suppose that a current flows in a wire that is stationary in the laboratory reference frame. Let us assume the current to be due to the flow of negative charges. To the observer in the lab frame the wire is electrically neutral, the numbers of positive and negative charges per unit length of wire being equal. But what does the wire "look like" to a negatively charged particle moving in the same direction and at the same speed as the charges moving in the wire?

To such a particle, the negative charges in the wire are stationary while the positive charges are moving. The question we now pose is , **to the moving particle, is the wire still electrically neutral?** According to STR, relative motion causes a shortening (contraction) of space along the direction of motion Hence, in the reference frame of the moving negatively charged particle,

- The average distance separating positive charges in the wire ***is smaller than the average distance separating negative charges.***
- This means ***the linear charge density of positive charges is greater*** than the linear charge density of the negative charges.
- Consequently, in the reference frame of the moving particle, the **wire is positively charged!** Since for equal lengths of the wire in the lab and moving frame the positive charge in the moving frame would be more while there is no change in the negative charge.

This would result in a Coulombic attractive force between **the moving negative charge and the net positive charge in the wire**. and it is this ***Coulomb (Electric) force*** that, in the lab frame is referred to as the ***magnetic force*** on the moving charge due to the electric current in the wire!

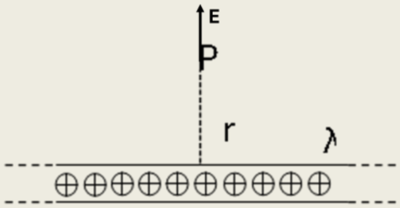
To see the connection between STR and magnetic field I will first list some well-known key results in electric fields, magnetic field. and STR that are generally introduced to students in classes XI, XII and UG. These results are obtained from Colomb's law, Biot-Savarts law etc. We shall adopt SI system of units.

1.Electric field due to an infinitely long line of charges

Consider an infinitely long line of charges of linear charge density λ (Fig 1) in a frame where the charges are at rest. Let P be a point at a perpendicular distance r from the line of charges. The magnitude of the Electric field at point P is

$E = \frac{2K_E \ \lambda}{r}$ where $K_E = \frac{1}{4\pi\epsilon_o}$ ------------ (1)

The direction of the E is away from the line of charges since we have assumed the charges to be positive



Fig(1) Electric Field due to an infinite line of charges

2.Magnetic field due to an infinitely long current carrying conductor

Consider an infinitely long straight conductor carrying a constant current I Fig(2). The magnitude of the Magnetic field at a point P which is at a perpendicular distance r from the conductor is given by

$B = \frac{2K_m \ I}{r}$ where $K_m = \frac{\mu_o}{4\pi}$ ------------(2)

The direction of **B** is **out** and perpendicular to the plane of the figure indicated by the dot at P

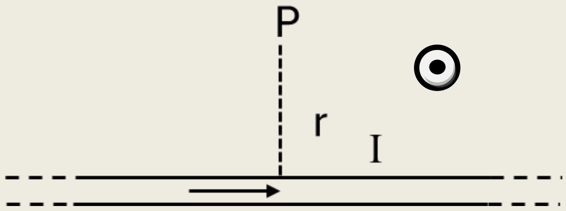


Fig (2) Field due to an infinite long conductor carrying a constant current I

3.Length Contraction

Consider an object which is at rest concerning an observer in a frame S placed along the X axis. The length as measured by the observer is L_O. This is called the *proper length* of the object. Now for an observer who is in a frame $S^/$ moving with a constant velocity v (v < c the speed of light) concerning S along the positive X axis (*we assume the three axes of S and $S^/$ are parallel and there is no relative motion between the frame along the Y or Z axis*). the object will appear to move with a velocity v along the **negative** x-axis.

According to STR the length L of the object measured by the observer in $S^/$ will be contracted along the direction of motion of the object and thus will appear shorter! i.e. $L < L_O$ Length L is referred to as *improper length*. This effect is known as ***Length contraction***. The relation between L and L_O is

$$L = \sqrt{1 - \frac{V^2}{c^2}}\ L_O \qquad \text{------------ (3)}$$

Since $\frac{V^2}{c^2} < 1$ it follows $\sqrt{1 - \frac{V^2}{c^2}} < 1$ and hence $L < L_O$.

Note: (1) The above expression is also expressed in the alternate form as $L = \frac{L_O}{\gamma}$

where $\gamma = \frac{1}{\sqrt{1 - \frac{V^2}{c^2}}} > 1$

(2) The effect is mutual for the observers in frame S and $S^/$

4. Charge Invariance (Conservation)

Consider a line of charges q distributed over the length l of an object. According to STR the total charge in an isolated system will be the same as measured by observers in two inertial frames of reference in relative motion. This is a consequence of the conservation of charge principle. It is to be noted, however, that ***this does not necessarily imply that the charge densities will be the same!*** The linear charge density will depend on the state of motion of the object within the two frames. This is a consequence of Length contraction.

5. Relation between Electric Permittivity (ϵ_0) and Magnetic Permeability (μ_0)

One of the fundamental results of Maxwells theory of electromagnetism is the relation between c, ϵ_0, and μ_0. $c = \frac{1}{\sqrt{\epsilon_0\ \mu_0}}$

Let us now understand how moving changes are a source of magnetic field.

Consider a long electrically neutral conducting wire at rest in frame S, carrying a current I to the left and a positive charge q at rest distant r from the wire. Let the current be due to the flow of negative charges to the right with a drift velocity v. We assume the negative charges to be a very long line of charges of linear charge density λ_- Cm^{-1}

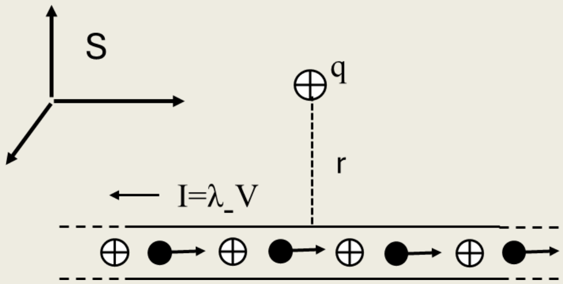


Fig (3) The point charge q at rest experiences no electric or magnetic force in frame S

In a time Δt the charge passing any point in the wire is the charge contained in a length vΔt which is

$\Delta q = \lambda_- \, v \, \Delta t$ ------------(4)

Hence the current for an observer in frame S is $I = \frac{\Delta q}{\Delta t} = \lambda_- v$ ------------(5)

Let the positive charge density in the wire be λ_+ . As the wire is electrically neutral $\lambda_+ = \lambda_-$, *Note that in this frame the positive charges are at rest*. Since by our assumption there is no net charge density(or charge), in the wire there ***is no electric force on the positive charge q***. Now let us observe the situation from frame **S/ which is moving to the right with a velocity v w.r.t the frame S**

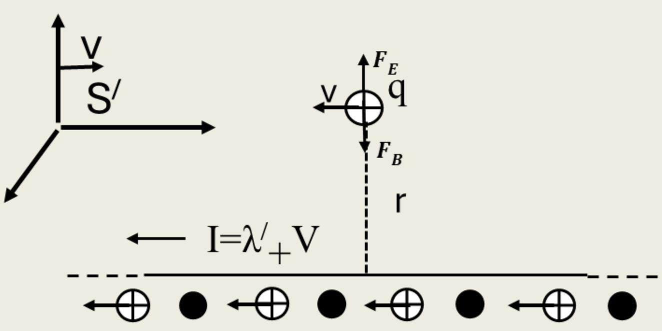


Fig (4) The point charge q experiences Electric & Magnetic force in frame S/

In this frame the negative line of charges will be at rest while the positive line of charges will move to the left with a velocity V. According to the STR if the total charges as measured in the two frames are the same *the charge densities will be unequal*. If we had N positive charges over a length L_O in the frame S ,now these N charges will be contained over a length L where,

$L = \sqrt{1-\frac{V^2}{c^2}}\ L_O$! Thus, the positive charge density ***will be greater*** $\lambda_+^/ = \frac{N}{L} = \frac{\lambda_+}{\sqrt{1-\frac{V^2}{c^2}}}$

However, the negative charge density ***will* be smaller**, since a length L containing a given number of charges (N) in this frame (where it is at rest) will be contained in a ***smaller length in S where it is moving with a velocity v.*** The negative charge density in the frame $S^/$ is

$$\lambda_-^/ = \sqrt{1-\frac{v^2}{c^2}}\ \lambda_-$$

The ratio of the charge densities in the frame $S^/$will be

$\frac{\lambda_+^/}{\lambda_-^/} = \frac{1}{1-\frac{v^2}{c^2}} \quad > 1\ which\ implies\ \lambda_+^/ > \lambda_-^/$ ------------ (6)

In arriving at equation (6) we have cancelled $\lambda_+ \& \lambda_-$ since $\lambda_+ = \lambda_-$.Since there is a net positive charge density, in the frame $S^/$ it follows that there will be an **electric field (E)** due to the line of charges at the site of the charge q, which will be directed away from the line of charges (wire).

This means the positive charge q at a distance r from the line of charges(wire) will experience a force F_E directed away from the wire. $F_E = qE$ Now using equation (1) we have $E = \frac{2K_E\,\lambda_{NET}}{r} = \frac{2K_E[\,\lambda_+^/ - \lambda_-^/]}{r} = \frac{2K_E\lambda_+^/\left\{1-\frac{\lambda_-^/}{\lambda_+^/}\right\}}{r}$ Using equation (6) and simplifying we get

$E = \frac{2K_E\lambda_+^/}{r}\left(\frac{v^2}{c^2}\right)$ ------------ (7)

The electric current in the frame $S^/$ is $I = \lambda_+^/ v \rightarrow \lambda_+^/ = \frac{I}{v}$ Substituting for $\lambda_+^/$ in equation (7) and simplifying we get $E = \frac{2K_E I}{r}\left(\frac{v}{c^2}\right)$ .Thus the Electric force on the charge q will be

$F_E = qE = 2\frac{K_E}{c^2}\ \frac{I}{r}\ qv$ ------------ (8)

This force(repulsive) is directed away from the wire. Now if this was the only force acting on the charge q, then the charge would have accelerated away from the wire. However, this is not the case as the charge is at rest with respect to the wire. It moves with a velocity v parallel to the wire in the in the same direction as the wire ! for the observer in $S^/$. *This means there must be another force on q (Let's say* $\boldsymbol{F_B}$*) which is directed towards the wire and whose* *magnitude is equal to F_E* . We assert that F_B is the **magnetic force.** *For the observer in $S^/$,* ***q is a moving charge*** *and the wire* ***has a constant current I.***

$$F_B = 2\frac{K_E}{c^2}\frac{I}{r}qv \text{ ------------ (9)}$$

we note that F_B is proportional to q ,v and I. From the principles of magnetism, the force on a charge q moving with a constant velocity v in a magnetic field B is

$\mathbf{F_B}$ = q (**v x B**) or F_B = q v B sin θ where θ is the angle between **v** and **B** vectors. If θ = 90^O then we have F_B = q v B .and the direction force is given by the usual rule of cross product. The magnitude of B is

$$B = \frac{F_B}{qv} = \frac{2K_E\, I\, qv}{c^2\, r\, qv} = \frac{2K_E\, I}{c^2\, r}$$

Using the relations $c = \frac{1}{\sqrt{\epsilon_O\ \mu_O}}$, $K_E = \frac{1}{4\pi\epsilon_o}$ and $K_m = \frac{\mu_o}{4\pi}$ we have $K_E = K_m c^2$

$$B = \frac{2K_m I}{r} \text{ ------------ (10)}$$

Since $\mathbf{F_B}$ is directed towards the wire downward(-ve y direction) and **v** of the charge q is towards the left (-ve x direction) for the observer in $S^/$ it is clear that The direction of **B** is **out** and perpendicular to the plane of the figure (4).

Equation (10) is the expression for the magnetic field due to an infinitely long

current carrying wire as mentioned in equation (2) ! which can be deduced from Biot Savarts law.

We thus note that the magnetic field produced by a current-carrying wire and the magnetic force such a wire exerts on a moving charge can be understood based on STR and the principle of conservation of charge.

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R.G. Piccioni, James A. Garfield High School, Seattle, WA. AAPT

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Revolution in Physics: Top Quarks Created for the First Time at CERN

Sarah Johnson , Biomedical Engineer and Science Journalist

For the first time, scientists have successfully observed top quarks, ultrafast and unstable fundamental particles created in an Earth-based laboratory. This groundbreaking discovery, announced by the ATLAS collaboration at the Large Hadron Collider (LHC), represents a pivotal moment in our understanding of matter and the early seconds of the Universe.

What is a Top Quark?

Quarks are elementary particles that constitute matter. They are the building blocks of protons and neutrons, which in turn form the nuclei of atoms. There are six different types of quarks, known as “up,” “down,” “charm,” “strange,” “top,” and “bottom.” These particles are held together by fundamental forces, notably the strong nuclear force, mediated by another particle called a gluon.

The top quark is unique for several reasons. First, it is the heaviest of all quarks. Although only slightly more massive than a proton, it is much more challenging to study due to its unstable nature. Indeed, the top quark decays extremely quickly (in only 5×10^-25 seconds), a timeframe so brief that it is nearly impossible to measure with our instruments. This instability makes the top quark a difficult particle to observe in nature, highlighting the significance of the observation made at the LHC.

The LHC and Lead Ion Collisions

The LHC is the world’s largest particle accelerator, located at CERN in Switzerland. This massive accelerator collides particles at speeds close to that of light, recreating extreme conditions similar to those just after the Big Bang.

One of the experiments conducted at the LHC involves colliding lead ions, highly energetic nuclei of lead atoms. These collisions generate temperatures and pressures similar to those of the early Universe, allowing scientists to simulate the quark-gluon plasma, a state of matter that existed in the first fractions of a second after the Big Bang.

This plasma is a chaotic soup of quarks and gluons, where quarks are not bound to form protons and neutrons but float freely. Observing particles like the top quark in this context is crucial, as it helps us understand how quarks and gluons interact under these extreme conditions and how the Universe evolved in its infancy.

Why is This Discovery Revolutionary?

One of the most fascinating aspects of this discovery is the role of the top quark as a temporal marker in the study of the quark-gluon plasma. Since top quarks decay very rapidly, scientists can use these decays to study the evolution of the plasma itself. Each observed top quark in these lead ion collisions can then provide information about the conditions at a specific moment in this primordial plasma.

The observation of the top quark also offers a unique opportunity to explore the interior of protons and neutrons, the components of atomic nuclei. By studying how momentum (or speed) is distributed among the quarks and gluons in these particles, researchers hope to better understand the fundamental properties of matter and energy in the Universe.

A Window into the Infinitely Small and the Infinitely Large

Observing top quarks is not just a technological feat. It also pushes our understanding of matter and the forces governing the Universe to an unprecedented level. By studying such fundamental particles, researchers hope to answer some of the biggest questions in modern physics: How do fundamental forces interact? What are the properties of the particles that make up atoms and nuclei?

The results of this experiment could also help explore even more complex phenomena, like the nature of dark matter or dark energy, mysterious elements that make up a large part of the Universe but still elude our understanding.

The Next Steps in Research

Scientists involved in this discovery are already preparing to deepen this research. The observation of the top quark is a key step, but it is just the beginning. In the coming years, new experiments will allow for a more detailed study of the decays of top quarks and their products, such as the W boson, a mediator of the weak nuclear force.

These studies will enable a better understanding not only of the properties of matter but also of the Universe's earliest moments.

In summary, the observation of top quarks at the LHC marks a major milestone in particle physics. By allowing us to observe such extreme phenomena, this discovery could revolutionize our conception of the Universe and open new perspectives on matter, fundamental forces, and the origins of our cosmos.

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New Theory Unites Quantum Mechanics and General Relativity

Joseph Shavit – Space, Technology and Medical News Writer

In a cutting-edge development that has sent shockwaves through the scientific community, researchers at University College London (UCL) have unveiled a radical theory that seeks to reconcile two pillars of modern physics – quantum mechanics and Einstein's general theory of relativity.

These two theories, which have been the foundation of physics for over a century, have long been at odds with each other, and their unification has remained an elusive quest.

Today, we dive into the world of quantum gravity, a field of study that aims to bridge the gap between the quantum realm, which governs the behavior of particles at the smallest scales, and the macroscopic world, where gravity shapes the very fabric of spacetime.

While the prevailing consensus has been that Einstein's theory of gravity must be modified to fit within the framework of quantum theory, a new theory, coined as a "postquantum theory of classical gravity," challenges this assumption in a thought-provoking way.

The Clash of Titans: Quantum Mechanics vs. General Relativity

Quantum mechanics and general relativity, developed by Albert Einstein in the early 20th century, have both stood the test of time and have been proven accurate in their respective domains. However, when it comes to merging these two theories into a single, comprehensive framework, the scientific community has hit a roadblock.

Quantum mechanics, which beautifully describes the behavior of particles at the subatomic level, operates in a probabilistic realm characterized by wave functions and quantum states.

In contrast, general relativity paints a different picture of the universe, where gravity arises from the curvature of spacetime caused by massive objects. While these theories excel in their own domains, they clash when brought together, leading to mathematical inconsistencies and contradictions.

A New Approach: Spacetime as Classical

Enter Professor Jonathan Oppenheim and his team at UCL, who have challenged the status quo with their groundbreaking theory. In two parallel papers published simultaneously, they propose a novel perspective that suggests spacetime may remain classical and unaffected by quantum mechanics.

This theory, as described in a paper published in Physical Review X (PRX), refrains from modifying spacetime itself and instead modifies quantum theory.

The core tenet of this theory is that spacetime remains classical, not subject to the constraints of quantum theory. Instead, quantum theory is tweaked to account for intrinsic unpredictability mediated by spacetime. What is the consequence?

Spacetime experiences random and violent fluctuations that exceed the expectations set by quantum theory. These fluctuations, if measured precisely enough, render the apparent weight of objects unpredictable.

To put their theory to the test, the researchers propose a groundbreaking experiment aimed at detecting fluctuations in mass over time. For instance, consider a 1kg mass – the standard measurement used by the International Bureau of Weights and Measures in France. If the measurements of this 1kg mass exhibit fluctuations smaller than those required for mathematical consistency, it would challenge the new theory.

This experiment, which has far-reaching implications for our understanding of gravity and quantum mechanics, is not just theoretical but practical. It serves as a critical juncture in the ongoing debate between competing theories of quantum gravity.

Professor Oppenheim, along with Professor Carlo Rovelli and Dr. Geoff Penington, leading proponents of quantum loop gravity and string theory, respectively, have even placed a 5000:1 odd bet on the outcome.

Five Years of Rigorous Testing

The UCL research group, led by Professor Oppenheim, has spent the past five years meticulously developing and examining their theory, scrutinizing its consequences from various angles.

As Professor Oppenheim puts it, "Quantum theory and Einstein's theory of general relativity are mathematically incompatible with each other, so it's important to understand how this contradiction is resolved."

Their journey has been marked by relentless exploration of the fundamental nature of gravity and the cosmos itself, probing the boundaries of our knowledge and challenging preconceived notions.

Beyond the Weight of Gravity: Implications of the Postquantum Theory

While the focus of the postquantum theory is on reconciling quantum mechanics and general relativity, its implications extend far beyond the realm of gravity. One notable consequence is the elimination of the notorious "measurement postulate" in quantum theory.

This postulate, which has long perplexed physicists, posits that measurements collapse quantum superpositions into definite states. In the new theory, quantum superpositions naturally localize through their interaction with classical spacetime, obviating the need for this postulate.

Professor Oppenheim's journey to this groundbreaking theory was motivated by his attempt to unravel the mysteries of the black hole information paradox. According to standard quantum theory, information cannot be destroyed.

Therefore, an object entering a black hole should somehow radiate information back out. However, this concept directly contradicts general relativity, which posits that once an object crosses a black hole's event horizon, it becomes inaccessible.

The postquantum theory offers a unique perspective, suggesting that the fundamental breakdown in predictability inherent to spacetime allows for information to be destroyed, resolving this long-standing paradox.

The proposal to test whether spacetime remains classical by detecting random fluctuations in mass is just one part of the puzzle.

Another experimental proposal aims to verify the quantum nature of spacetime through a phenomenon called "gravitationally mediated entanglement." These experiments, though challenging, hold immense promise in advancing our understanding of the fundamental laws of nature.

Professor Sougato Bose, an expert in the field who was not involved in the recent UCL announcement but had previously proposed the entanglement experiment, emphasized the importance of these endeavors, stating, "Experiments to test the nature of spacetime will take a large-scale effort, but they're of huge importance from the perspective of understanding the fundamental laws of nature. I believe these experiments are within reach – these things are difficult to predict, but perhaps we'll know the answer within the next 20 years."

At the heart of this theory lies a delicate interplay between quantum particles, such as atoms, and the fluctuations in classical spacetime. These fluctuations, if the theory holds, must occur on a scale yet to be detected but should be large enough to impact quantum particles' behavior.

The proposed experiments seek to find this elusive balance, shedding light on whether spacetime remains classical or succumbs to quantum mechanics at microscopic scales. In the words of Professor Oppenheim, "Now that we have a consistent fundamental theory in which spacetime does not get quantized, it's anybody's guess." The journey has just begun, and the future of physics has never looked more intriguing.

Background information

Quantum mechanics background

All the matter in the universe obeys the laws of quantum theory, but we only really observe quantum behavior at the scale of atoms and molecules.

Quantum theory tells us that particles obey Heisenberg's uncertainty principle, and we can never know their position or velocity at the same time. In fact, they don't even have a definite position or velocity until we measure them. Particles like electrons can behave more like waves and act almost as if they can be in many places at once (more precisely, physicists describe particles as being in a "superposition" of different locations).

Quantum theory governs everything from semiconductors which are ubiquitous in computer chips, to lasers, to superconductivity to radioactive decay. In contrast, we say that a system behaves classically if it has definite underlying properties.

A cat appears to behave classically – it is either dead or alive, not both, nor in a superposition of being dead and alive.

Why do cats behave classically, and small particles quantumly? We don't know, but the postquantum theory doesn't require the measurement postulate, because the classicality of spacetime infects quantum systems and causes them to localize.

Gravity background

Newton's theory of gravity, gave way to Einstein's theory of general relativity (GR), which holds that gravity is not a force in the usual sense. Instead, heavy objects such as the sun, bend the fabric of spacetime in such a way that causes the earth to revolve around it. Spacetime is just a mathematical object consisting of the three dimensions of space, and time considered as a fourth dimension. General relativity predicted the formation of black holes and the big bang. It holds that time flows at different rates at different points in space, and the GPS in your smartphone needs to account for this in order to properly determine your location.

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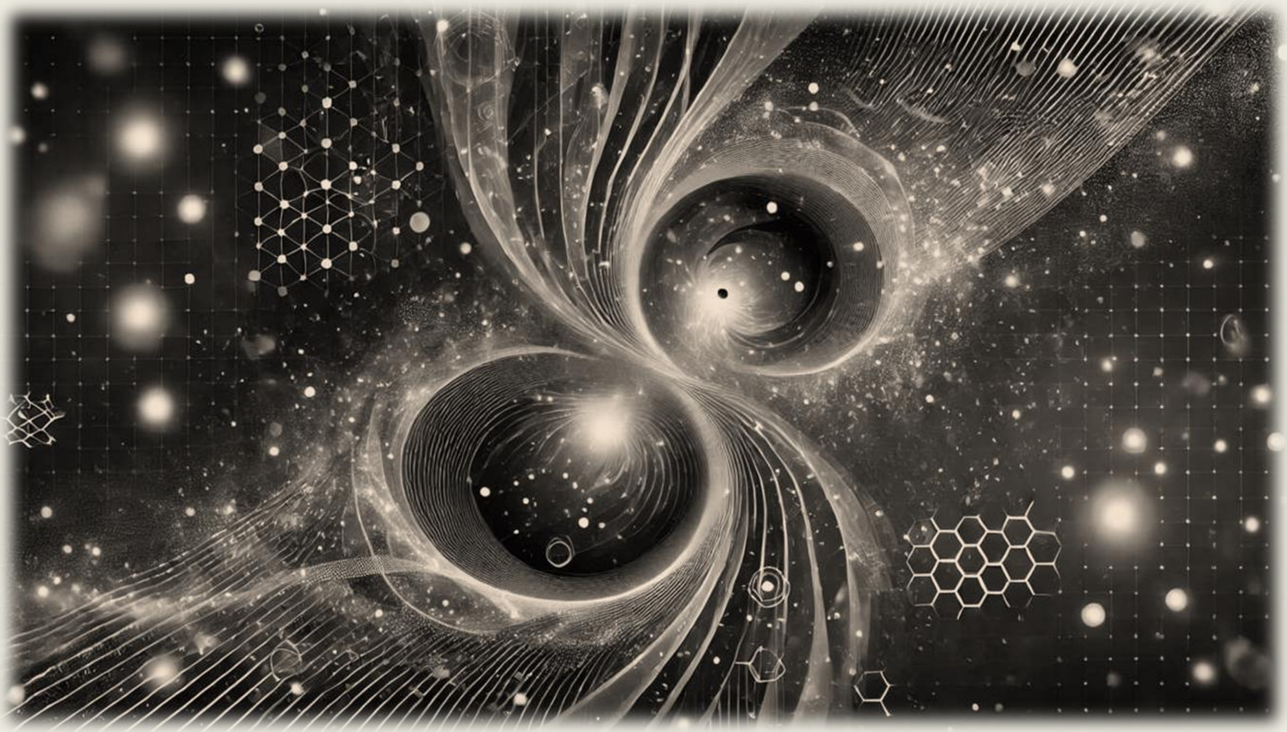

World's Largest Radio Telescope to Unveil Dark Matter and First Galaxy Secrets

Robert Lea, Senior Science Journalist, U.K.

A feature of light absorption by hydrogen surrounding early galaxies could be used as a novel new probe into the mysteries of dark matter and how it influenced the evolution of the universe during the cosmic dark ages.
Scientists have long theorized that dark matter, a mysterious substance that makes up around 85% of the matter in the universe, played a huge role in the formation of early galaxies. But because dark matter doesn't interact with light (unlike the "normal" matter that makes up stars, planets and us), its nature remains unknown. That means the precise role it played as galaxies began to form remains a gap in cosmological models.

To investigate this puzzle, scientists from Northeastern University in China and the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC) have suggested a novel probe to shed light on both the nature of dark matter and the early formation of galaxies.

One possible way of investigating the particles that comprise dark matter and their mass has been by studying small-scale structures in the universe. The problem comes when attempting to do this for a period called "cosmic dawn," around 380 million years after the Big Bang, a time when the earliest stars were just being born. There were thus few viable light sources to illuminate this ancient epoch for astronomers.

But there were atoms during this era, in the form of a gas of the lightest chemical element, hydrogen. Like all elements, hydrogen absorbs light at characteristic wavelengths, leaving its fingerprint on light passing through it.

Searching for dark matter in a cosmic forest

Atomic hydrogen gas in and around the small-scale structures that existed during the cosmic dawn, which ended around one billion years after the Big Bang, creates characteristic absorption lines at 21 centimeters, in the radio range of the electromagnetic spectrum. These are collectively called the 21-cm forest, which has been proposed as a potential probe of gas temperature and dark matter during cosmic dawn for over 20 years.

This has remained just a theoretical concept, however, due to the fact that light from this era has been traveling for around 13.4 billion years to reach us. Along the way, it has lost energy and had its wavelength stretched and its frequency lowered, moving it down the electromagnetic spectrum toward the red region and beyond to infrared.

The more distant the source of light, the more extreme this "redshift" process is. With starlight absent, using the 21-cm forest as a dark matter probe requires radio-loud sources like quasars to be seen at cosmic dawn and thus at high redshift. But signals from such radio sources in this epoch are faint, and these high-redshift background sources are difficult to identify.

This situation may be about to change, however. Not only have a number of high-redshift radio-loud quasars been discovered recently, but the world's largest radio telescope, the Square Kilometre Array (SKA), began construction in Australia and South Africa in December 2022 and will soon open its sensitive radio eye on the universe. This suggests that detecting and using the 21-cm forest may soon be feasible.

SKA Observatory is expected soon-to-be largest radio telescopes in the world.

The team behind the new study thinks that measuring the distribution of energy of the 21-cm forest, or its "power spectrum," will make it a plausible probe to simultaneously measure dark matter properties and the thermal history of the universe.

This could help researchers distinguish between a cold dark matter model of the universe — one with massive dark matter particles moving slowly in comparison to the speed of light — and a hot dark matter model, with lighter and more fast-moving dark matter particles.

"By measuring the one-dimensional power spectrum of the 21-cm forest, we can not only make the probe actually feasible by increasing the sensitivity, but also provide a way to distinguish the effects of warm dark matter models and early heating process," said National Astronomical Observatories researcher Yidong Xu, corresponding author of the new study. "We will be able to kill two birds with one stone!" SKA) is an international radio telescope project with telescopes all over the world.

As long as cosmic heating wasn't too extreme during cosmic dawn, the low-frequency capabilities of phase 1 of SKA's operations should mean scientists can constrain the mass of dark matter particles and gas temperature. If cosmic heating was too great, then the second phase of SKA will see the instrument enlarged, leading to the use of multiple background radio sources delivering the same constraints.

As the potential use of the 21-cm forest as a dark matter probe is tied to observations of high-redshift background radio sources, the next step in this research is identifying more radio-bright sources during the cosmic dawn, including more radio-loud quasars and the afterglows of gamma-ray bursts.

These sources can then be followed up once SKA begins observing the universe in 2027, thus allowing astronomers to shed more light on the mysteries of both dark matter and the first galaxies.

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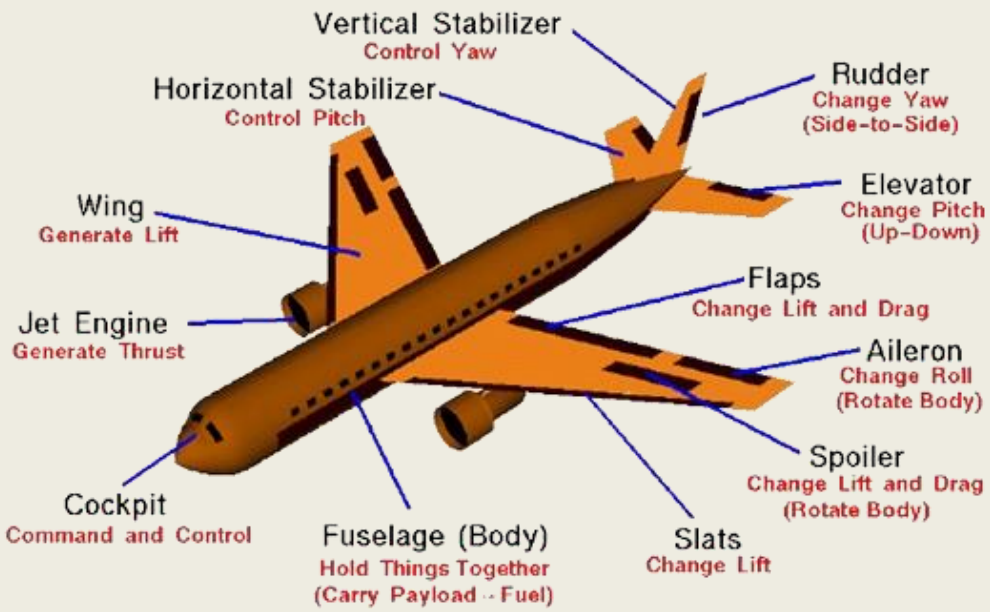
How Airplanes Fly – A Brief Accont

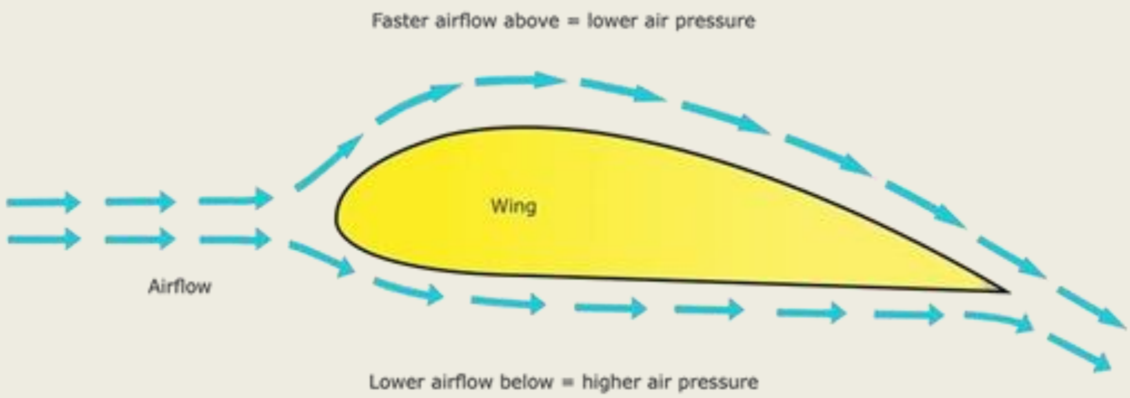
Dr. B.A. Kagali, Professor of Physics (Retd.) Bangalore University

Who is not wonderstruck by the sight of huge metallic machines called airplanes, carrying so many people and cargo, flying in the air like birds and traveling great distances in a short time? They are indeed great wonders of science and technology that have revolutionized the world of travel and transportation. Airplanes began to appear on the scene after the pioneering efforts of the Wright brothers in the USA during 1903-1905. The two brothers demonstrated, for the first time, how controlled flight of heavier-than-air machines could be achieved. Since then, many improvements and modifications have been made to their engines and structures, making airplanes reliable, comfortable, fast, and safe modes of travel and transport over long distances. This short article discusses the most basic aspects of airplane design and operation for the benefit of curious students and novices.

The main parts of airplane



The body of the plane is called its fuselage (see the figure, courtesy NASA). It is generally a long, tube-shaped part, where the pilots and passengers are seated. In a small plane, the engine that spins specially designed blades, called propellers, is located in the front part of the plane, known as the nose. While spinning, the blades propel or push a large amount of air toward the back of the plane at high speed. In larger planes, specialized engines called jet engines are attached to the wings, and there are no propeller blades (see figure). The jet engines push enormous amounts of compressed air backward at a high rate, generating the forward force of the plane, called thrust, in accordance with Newton's third law of motion. The wheels of a plane form the landing gear. There are two main wheels on either side of the plane's fuselage. For



Source: NASAnNhttps://www.sciencelearn.org.nz/

stability, there is one more wheel near the front of the plane. The landing gear can be folded into the fuselage during flight and extended for landing in larger planes. In smaller planes, the landing gear cannot be folded.

All planes have right and left wings that are attached to the fuselage—either on top or to the sides of the fuselage. The wings are specially shaped with smooth surfaces. The top surfaces are slightly curved from the front (or leading edge) to the back (or trailing edge), as shown in the figure. The top surface is curved more than the bottom surface. High-speed air moving around the wing produces the upward lift for the airplane. The shape of the wings determines how fast and high a plane can fly. Wing shapes are designed by performing tests in wind tunnels.

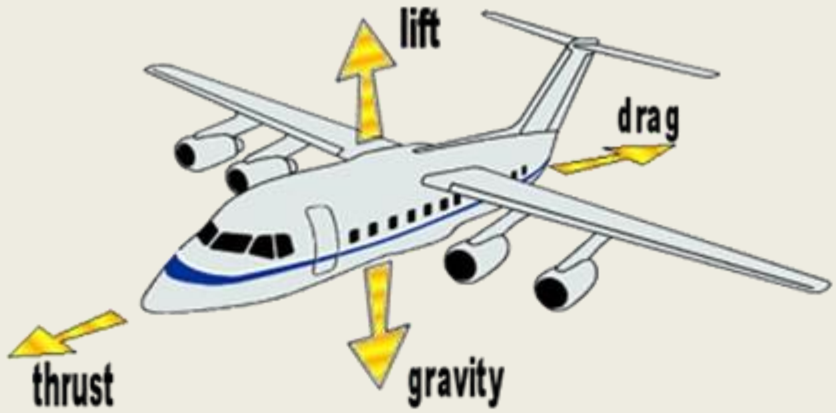
Each wing has two movable plates called flaps and ailerons, which are connected to the backs of the wings with hinges. The flaps slide back and down to increase the surface area of the wings. They also tilt downward to increase the curvature of the wing, which helps during takeoff and landing. The ailerons are hinged closer to the edges of the wings and can move vertically up and down. The left and right ailerons always move together in opposite directions. They are used to tilt the wings up or down, causing a motion called rolling. This helps the plane turn smoothly to the left or right.

Usually, they are operated along with a movable metal plate called the rudder, which is hinged to the backside of the tail. The tail, located at the rear of the plane, provides stability. It consists of two parts: the horizontal stabilizer and the vertical stabilizer. The rudder, attached to the back of the vertical stabilizer, can be moved left or right to control the plane's left or right movement (yaw).

There are movable plates called slats on the front part of the wings. These extend the wing area during takeoff, helping the plane generate more lift. Additionally, two hinged parts called elevators are attached to the back of the horizontal stabilizer at the rear of the plane. These can be raised or lowered together to change the direction of the plane's nose, a movement known as pitch. When the elevators are raised, the plane's nose moves up, and when lowered, the nose moves down, causing the plane to ascend or descend.

Special metal plates called spoilers, hinged in the middle part of the wings, act as air brakes in larger planes to reduce speed during landing. However, spoilers are not present in smaller planes.

Forces on a Plane



Four kinds of forces normally act on a flying plane (as shown in the figure). The gravitational force, due to the Earth, acts downward, pulling the plane toward the ground. The engine, which spins the propeller blades or operates a jet engine, produces a forward force by displacing a large mass of air backward at high speed. According to Newton's third law, the displaced air pushes the plane forward with an equal and opposite force, known as thrust.

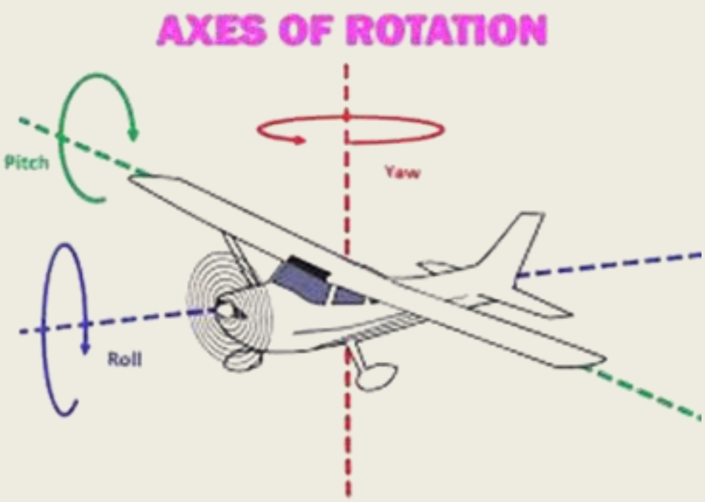
Airplane wings have specially designed surfaces that cause air to move faster over the top surface, which has a greater curvature. When air moves faster in a region, the pressure decreases in that region, as stated by Bernoulli's principle. This results in lower air pressure on the top of the wing compared to the bottom, creating a force called lift that pushes the plane upward. The lift force is proportional to the square of the velocity and the surface area of the wings. For a plane to rise from the ground and fly, the lift must exceed the gravitational downward force (its weight).

Meanwhile, the air surrounding the plane creates a drag force, which opposes the forward motion, similar to friction. Once the plane generates enough thrust to overcome both the drag and gravitational force, it can lift off and maintain flight.

Controlling the Flight

How does a plane perform different maneuvers? A pilot has special controls within reach to guide the plane. Using levers and buttons, the pilot can change the plane's motion in three ways: pitch, roll, and yaw (see the figure).

Pitch refers to the up-and-down movement of the plane’s nose, turning about an axis that runs through the wings. To control pitch, the pilot adjusts the elevators on the tail. Lowering the elevators causes the tail to lift (according to Bernoulli’s principle), which lowers the plane's nose, initiating a descending motion. Conversely, raising the elevators lowers the tail and lifts the nose, causing the plane to climb. This maneuver is crucial during takeoff or ascent**.**



To roll the plane to the right or left, the ailerons are raised on one wing and lowered on the other simultaneously. The wing with the lowered aileron rises whiles the wing with the raised aileron moves down, once again following Bernoulli principle. To roll the plane to the left, for example, the right aileron is lowered while the left aileron is raised at the same time. Note that rolling is nothing but angular motions about an axis passing through the fuselage and is controlled by the ailerons.

Yaw is the turning of a plane about an axis that is passing vertically upwards through the center of the plane. When the rudder is turned to one side, say to the left, there is a net force acting towards the right on the tail (again from the Bernouille principle). As a result, the nose of the plane turns to its left. For turning the plane rightward, the rudder is moved to its right. Hence, the airplane's nose is pointed in the same direction as the direction of the rudder. The rudder and the ailerons are used together to make a turn to the left or right in a smooth manner.

The pilot controls the engine power using the throttle. Pushing the throttle increases power, causing the plane to lift up. If the elevators are pushed up at the same time, the nose gets lifted and the plane climbs up. While landing, the power of the engine is reduced while the elevators are pushed down from their normal position to lower the nose direction.

Hence, all the three motions – pitch, roll and yaw – are achieved by moving, relatively, small surfaces on a plane while high speed air is passing over them!

The pilot uses brake pedals to reduce the speed of the landing wheels after they touch the ground from a flight in the air. In bigger planes, there are plates, called spoilers, that are hinged to the wings and are made to stand up vertically on the wings (offering greater resistance to air) to reduce the speed of a plane moving on the runway after touchdown.

Of course, there are so many parts and devices such as fuel tanks, air conditioners, speedometers, altimeters, radio transmitters, and batteries are essential for flight.

However, it can be seen that the movements of a plane are cleverly controlled by small movements of various attachments (slats, flaps, ailerons, spoilers, elevators) to its wings and tail, effectively using the power of moving air! Mechanical, electrical and electronic devices are used to perform such movements. One can try to identify such movements of an airplane to marvel at a technological feat!

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How Airplanes Fly

A child gazes at an airplane soaring above and asks, “How does it stay up in the air?”

The parent smiles and says, “It all starts with the wings. When the plane moves forward, air flows faster over the top of the wings than underneath. The shape of the wings creates **lower pressure above** and **higher pressure below**, which generates **lift**—this helps the plane rise.

“Then, the engines provide **thrust**, pushing the plane forward, allowing the wings to create enough lift to overcome gravity. But the plane also has to fight **drag**, which is air resistance that slows it down. The balance between these forces—**lift**, **thrust**, **drag**, and **weight**—is what keeps the airplane flying smoothly.”

The child, now fascinated, nods. “So, it’s like the plane needs all of these things working together to stay in the air?”

“Exactly,” the parent replies, watching the plane glide effortlessly across the sky.

Bibha Chowdhuri, A Poineer Cosmic Ray Physicist

Palahalli Vishwanath (Former Professor, TFIR, Bombay

One of the snippets in a newspaper from a few years ago had this to say about a woman physicist from the first part of the 20th century: “Bibha was supposedly India's first woman researcher. Yet, neither does the name of this gifted physicist surface in any book on inspiring Indian women, nor is she mentioned amongst various lists of Indian pioneers in the history of science. Bibha also did not win any national award or receive a fellowship from a renowned scientific society during her lifetime.” The Bibha referred to in the note is Dr. Bibha Chowdhuri, and this is a brief article on this neglected great pioneer of Cosmic Ray Physics. The interested reader is referred to an erudite and exhaustive article by Naba Mondal covering various aspects of her life and research. I should note that I was fortunate to have interacted briefly with her during my student days.

Bibha as student

Bibha Chowdhuri (Fig. 1) was born in 1913 in Calcutta to a Brahmo family of considerable means. Given their modern outlook on life, it was no surprise that the family wanted good education for their children. Bibha Chowdhuri studied physics at Calcutta University which previously had Prof C V Raman on its faculty. Prof Raman had already been conferred with the Nobel Prize a few years earlier for his pioneering work in optics. Prof Raman’s work had also provided evidence for particle nature of light. Bibha Chowdhuri was the only woman in a class of 24 students. She completed the M.Sc. degree in the year 1936. Normally even today many students, especially women, who complete their MSc opt for teaching. Instead, she preferred to do research and joined Prof Debendra Mohan Bose (1885-1975) in Calcutta University. Later in 1938 Prof Bose left the University to join the Bose Institute founded by the venerable scientist Jagdish Chandra Bose. Bibha Chowdhuri went with Prof DM Bose to the institute and her work with him for the next few years is an important chapter in the lives of both scientists and of Particle Physics research in the country.

Fig 1

Debendra Bose did his initial studies in Calcutta and later went to England in 1907 for further studies, where he worked with stalwarts like J.J. Thompson, the discoverer of the electron and C.T.R. Wilson, the pioneer inventor of the Cloud Chamber. Later, he returned to Bengal in 1913 and became Professor of Physics in Calcutta University. He was instrumental in influencing several younger colleagues including Satyendra Nath Bose who eventually discovered Bose -Einstein statistics and thus lent his name to the even spin particles. He went back to then West (Germany) in 1914 and stayed there for 5 years during which he interacted with the cream of German scientists like Albert Einstein, Max Planck and others. He also received the PhD degree from Humbolt University in 1919. He became the director of Bose institute in 1 938 and served there for 29 years His contributions are in the field of Cosmic Rays, Artificial Radioactivity and Neutron.

At this time, we digress to discuss briefly the Nuclear Emulsion technique which was the medium used by Bose and Chowdhuri in their path breaking research.

The Nuclear Emulsion Technique

The standard charge particle detectors in early 20th century were the ionization chambers (and its different avatars like the GM counter), the scintillation detectors and the Cloud Chamber. Along with these there was also the Nuclear Emulsion which was a take-off from simple photography. It uses a photographic plate with a higher concentration of Silver Halide grains. It has the primary advantage of extremely high spatial precision and resolution, quite superior to even the more modern detectors in particle physics. Another great advantage was that the emulsion stacks can be left exposed to Cosmic Rays for a very long time.

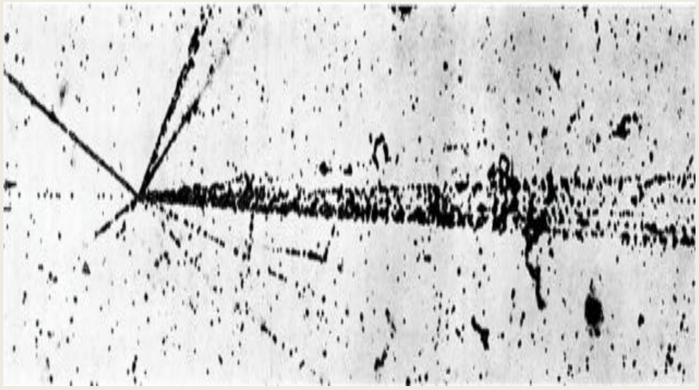

Fig 2

It owes its beginning to Henri Becquerel who discovered in 1896 the phenomenon of Radioactivity when he found the blackening of photography paper wrapped up with some uranium salts. Later, Ernest Rutherford, a pioneer in many aspects of Nuclear Physics, Kinoshita and others improved the emulsion technique for detection of different types of particles. Further progress in the technique is due to an Austrian physicist Marietta Blau (1894-1970) who was the first to detect a track of proton in emulsions. In 1937 she also devised a method to find the energy of particle depending upon the distance between the exposed silver grains along the tracks.

She also discovered ‘stars’ in photographic plates which are due to particle tracks from nuclear reactions (Fig. 2 shows an example) and showed the immense possibility of nuclear emulsions in these studies. Soon after her important discoveries, she had to leave Germany because of Nazi persecution and spend time in various laboratories in Europe, Mexico and the USA. Even after she returned to post-war Austria, she did not get employment commensurate with her abilities. She had to work without any pay several times in her life and she died of cancer in 1970 in Vienna. Her death was almost unnoticed. Her life was probably typical of women in scientific fields, even in relatively enlightened countries of Europe.

Calcutta and the new particles

Progress in Emulsion Technique continued in India under the guidance of Debendra Bose, whose group Bibha Chowdhuri joined as a researcher. In 1938, the Indian Science Congress took place in Calcutta. Among the many foreign scientists who attended the Congress was Walter Bothe, the pioneer Cosmic Ray scientist from Germany. From him Debendra Bose learnt about the exciting work by Blau and associates. This immediately induced him and Bibha Chowdhuri to work with emulsions.

The great excitement for experimentalists at that time was the possible discovery of new particles. Chadwick had discovered the Neutron, another constituent of the nucleus, in 1932. In the same year Anderson had discovered the Positron, the twin particle of the electron, among secondary Cosmic Rays. Few years later (1936) there was another discovery in secondary Cosmic Rays by Anderson and Niedermeyer, that of Muon (also called Mu Meson at that time). Meson (actually called Mesotron for few years when Bhabha suggested the simpler word meson) had entered the physicist's world through Yukawa, the Japanese theoretical physicist. He had suggested that nuclear forces between nucleons is mediated by a low mass particle and he had estimated its mass as 200 times that of electron. For some time, Muon was thought of as Yukawa's particle but given up because it could penetrate matter and did not have strong interactions. So, the search for Yukawa particle had become the holy grail of experimental particle physicists.

Bose and Chowdhuri bought half tone emulsion plates of 70-micron thickness from ILFORD company. They exposed these plates at three different altitudes – Darjeeling, Sandakphu and Pheri Jong (Tibet) with altitudes of 7000ft, 12000 ft and 14500 ft respectively for period of 6-9 months. The plates were then taken back to Calcutta. For calibration, they also had proton tracks from radioactive experiments. When they started analysing the plates, they noticed that the plates from mountains displayed large curved tracks with significant scattering whereas proton tracks had minimal scatter. Apart from it, the proton tracks had much higher energy deposition than Cosmic Ray tracks. They devised methods to eventually get the mass of the particle responsible for the track and published two papers in NATURE explaining their methodology. Roy and Singh state "… From measuring the length of the track, scattering, mean grain spacing etc., Bose and Chowdhuri determined the physical properties of the detected particle such as its mass, energy, momentum, etc". The reader is referred to that article as also the one by Mondal for detailed report on their methods and results.

In their two final papers in NATURE ('A photographic method to measure the mass of the Mesotron'), Bose and Chowdhuri attempted to derive the mass of the particle responsible for the tracks. According to Mondal, they give their estimates as 217 +/- 30, 336 +/- 20, and 313 +/- 20 in units of electron mass. They also note that the second and the third estimates could have contamination from protons. They needed better quality emulsions for further research to improve the mass estimates but war intervened and they had to stop the experiment. Thus, came to halt a very important experiment by Indian physicists in Particle Physics. There have been some discussions on whether the particles detected by Bose and Chowdhuri are pi mesons or muons. Here we just note that the mass of the muon is ~206 electron mass and of the pion is ~ 280 electron mass. Bibha Chowdhuri's contribution to this endeavour cannot be over stressed. This was certainly the pinnacle of her research and it is a mystery why she did not choose to write her thesis on this very important work.

Later C.F. Powell used improved photographic plates (full tone) and discovered the pi meson in 1947 for which he got the Nobel Prize three years later. Powell did acknowledge the contribution of Bose and Chowdhuri to the field "In 1941, Bose and Chaudhuri had pointed out that it is possible, in principle, to distinguish between the tracks of protons and mesons in an emulsion... they concluded that many of the charged particles arrested in their plates were lighter than protons, their mean mass being 200 electron mass. The physical basis of their methods was correct and their work represents the first approach to the scattering method of determining momenta of charged particles by observation of their tracks in emulsion"

Bhibha in West

After the war, Bhibha Chowdhuri joinedthe famous Patrick Blackett (1897-1974) in 1945 at Manchester for doctoral studies. Blackett's fame rested on the concept of the counter-controlled Cloud Chamber; he had studied earlier under Rutherford and in 1932, together with G.P.S. Occhialini, improved on the cloud chamber technique in which they managed to make cosmic rays take their own photographs (Fig 3 shows the iconic photo of a positron track in a cloud chamber taken by Anderson)

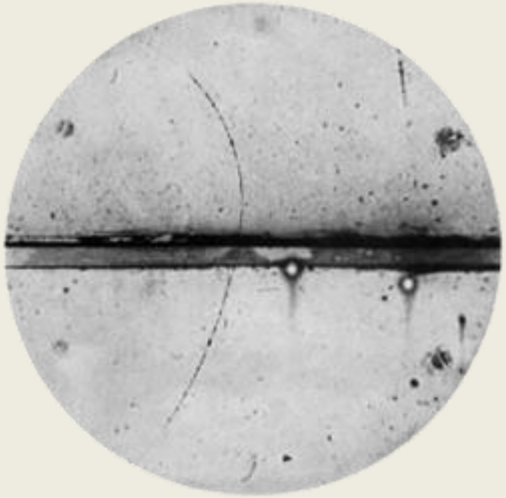

Fig.3

Blackett had diverse interests and conducted rock magnetism studies which supported the theory of continental drift. He was also the adviser for Prime

Minister Nehru in matters of defence. He was a champion of third world countries regarding economic matters.

Bibha Chowdhuri's experiment was a study of Extensive Air Showers (EAS) associated with the so-called penetrating component which included mostly muons. EAS consists essentially of thousands of particles created in several generations by the interaction of a Cosmic Ray primary particle with nitrogen in the atmosphere; these particles (mainly electrons, muons, photons, and variety of mesons) arrive simultaneously at the detectors. She set up several detectors (GM counters) to record and register the EAS particles and a detector under lead to study the penetrating component. A Cloud Chamber was triggered when both the EAS and the penetrating particle (mostly moons) were present. She worked for several years on this experiment and collected many many clouds chamber pictures. She presented all this in her thesis in 1948 which brought her the PhD degree. About her work in Manchester, Blackett wrote later to Homi Bhabha "…… Her examiners considered she did extremely well. I also have seen her thesis and it is very impressive".

Fig.4

Dr Bibha Chowdhuri returned to West several times later in her life (dates are not very certain here). She worked with the French physicist Leprince Ringuet in a high-altitude laboratory in Alps in 1956 and worked on decay of K mesons registered in cloud chambers (1954-1956) (Fig. 4 shows a photo of Dr Bibha Chowdhuri in a conference in Pisa in 1955). Later she spent two years in the University of Michigan (1957-1959) working on Cosmic Ray Extensive Air shower experiments with Dr Wayne Hazen. Before returning to India, she also worked on an EAS experiment by MIT which was starting up in New Mexico which furthered her expertise in EAS studies.

TIFR and PRL

Two premier institutions of fundamental science were founded in the same decade after independence by two visionaries of Indian science. Homi Bhabha started Tata Institute of Fundamental Research (TIFR) in 1945 in Bombay and Vikram Sarabhai founded Physical Research Laboratory (PRL) in 1947 in Ahmedabad. Both Bhabha and Sarabhai needed young people for various research programs; and both had made contributions to Cosmic Ray Physics and thus anxious to start experiments in this field. It is not surprising that Bibha Chowdhuri, herself a pioneer in Cosmic Rays, worked in both of these institutions.

Bhabha recruited Dr. Bibha Chowdhuri to head experiments with a cloud chamber. She was the first woman physicist to work in TIFR. At that juncture, TIFR had several youngsters who would conduct path breaking experiments; In particular, they were B.V. Sreekantan, R.R. Daniel, D. Lal and Y. Pal who started working on various problems of particle physics using different detectors. Bibha Chowdhuri started an experiment, somewhat similar to what she had in Manchester. Along with a younger colleague A. Subramanian, she used the Cloud Chamber to study the penetrating component and after few years of data taking, she came to the conclusion that the penetrating component was not restricted to muons and also had what came to be known later as hadrons. After five years, she decided to leave TIFR in 1954. She took up a lectureship in an engineering college in Bengal.

After a stint in the West as stated earlier, Dr Chowdhuri joined Physical Research Laboratory in 1959 to work with Vikram Sarabhai in setting up an EAS array in Kodaikanal. Due to various reasons, this effort was not successful. Later she decided to collaborate with TIFR which already had a large EAS array at KGF. She wanted to focus on interaction of muons in EAS. Along with a graduate student (Y.C. Saxena), she set up an underground detector with an energy threshold of 160 GeV for muons; the information about possible coincident EAS came from the large TIFR array. This experiment ran for almost a decade and yielded results on photo nuclear interactions of high energy muons. She retired from PRL after this experiment and returned to Bengal. While at PRL, she was also engaged in teaching and Dr Kasturirangan, ex ISRO Chief and one of her students, remembers her thus: ‘Her teaching prepared us for the more demanding challenges of research. What I remember more is her friendly disposition despite her serious appearance which resembled that of a school master”

She was 63 years old when she returned to Bengal in 1976. Her next years were spent in interaction with scientists in various institutions in Calcutta. She was also involved with several experiments conducted there. Bibha Chowdhuri died in obscurity at Calcutta in 1991. According to Roy and Singh, no obituary was published in any professional journal or periodical.

Conclusions

During her life, Bibha Chowdhuri had to face various hurdles, some especially connected with the fact that she was a woman. In patriarchal societies, like in most of the world, education was not considered a priority for women. She was lucky that her family valued education. However, at the very start of her research, she had to face antagonism from Debendra Bose who was not inclined to welcome her to his group. Western societies are also not free from these prejudices. Even liberal scientists like Blackett had doubts about the working of women in experimental sciences; in his recommendation he had suggested to Bhabha that she work in a group implying that she may not be able to manage by herself! We have seen earlier how Marietta Blau, the pioneer in emulsion studies, was also not given sufficient recognition and how she led a largely unknown life. Even later in 20th century, there have been glaring instances of misogyny with neglect of great discoveries by Jocelyn Bell and by Vera Rubin. According to Roy and Singh, it is possible that even premier institutions under visionaries like Bhabha and Sarabhai were not immune from prejudices. There are two mysteries regarding her stay in TIFR. Why did she not take up nuclear emulsion work? Was she not encouraged in that line or did she herself prefer cloud chamber work? Also why did she leave a good position in a premier institution like TIFR to take up a job, that too for a lower pay, for teaching engineering students? Even in PRL she was not offered a high position though she had worked for several decades in research.

It should also be noted that there is not much recognition anywhere in the world for individual experimental scientists working in large groups. It is worse when the scientist happens to be a woman. Two books devoted to women scientists of India and published in the first two decades of the 21st century also did not mention Bibha Chaudhuri at all!

It is some consolation that she is finally getting some recognition in this country. In a major tribute to her, the International Astronomical Union (IAU) named a star ‘Bibha’ after her in December 2019. She is the only woman scientist from India to have received such an honour. Also, out of 11 chairs instituted by the Govt of India named after women scientists, one has been named after Dr Bibha Chowdhuri.

We have already noted Dr Bibha’s great perseverance in research. We have to note that she was physically also a very strong person. Going to England, Europe and America in 1940s and 1950s meant long journeys alone by ship and she managed them very well. When working with Prof. Bose in the pioneering emulsion experiments, she had to go to several Himalayan hill stations. Even today these trips are arduous. Bibha Chowdhuri managed to go around these places on horses! Similarly, she would go to the underground experiment in KGF mines without any problems. A salute to the brave lady!

Lastly, she was a great supporter of women in science. “Women are terrified of physics– that is the trouble.” In an interview she said “In this age when science, and physics particularly, is more important than ever, women should study atomic power; if they don’t understand how it works, how can they help decide how it should be used? “It is true that there are more women in science today. Still, the world, and India in particular, needs many more women scientists like Bibha Chowdhuri.

Personal notes

TIFR was doing a Cosmic Ray Extensive Air Shower (EAS) experiment in KGF mines in the 1960s. I had done my MSc in Central College in 1962 and was taken as beginning graduate student for this experiment. It was around the same time (1965/66) that PRL also started a similar, but smaller, experiment. The group had Sri Yogesh Saxena, a student like me and Dr Bibha Chowdhuri, their head. She came quite often to KGF, and she worked very closely with us. We were apprehensive in the early days of a senior person like her but with time we grew accustomed to her. She always had a smile and was very nice to us and talked to us as equals. Our discussions centred around mundane but necessary details of the experiments. Dr Vikram Sarabhai also visited their experiment once.

Without enough maturity, we could not appreciate Dr Bibha Chowdhury for the pioneer she was and we were totally ignorant of her achievements. She was also not the one to talk about herself. Thus, it was a missed opportunity for me not to have learnt from her deep knowledge of the subject. This article is a humble tribute to that pioneering physicist.

Acknowledgements

I am grateful to the authors of the two references for information and insight into Dr Bibha Chowdhuri's life and research work. The figures 1, 3 and 4 are from Wikipedia; figure 2 is from CERN Courier.

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2. Suprakash C. Roy and Rajinder Singh: Bibha Chowdhuri – The First Woman Scientist at the TIFR, PHYSICS NEWS, 51, 1 (2021)

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- "Science is a journey of discovery, where every question leads to a deeper understanding of the universe."
- "In the pursuit of knowledge, every experiment is a step toward unravelling the mysteries of nature."
- "The beauty of physics lies not in the equations, but in the answers, they reveal about the world around us."
- "Through the lens of science, we see not only the universe but also the infinite possibilities of human potential."

Hans Berger: The Father of EEG

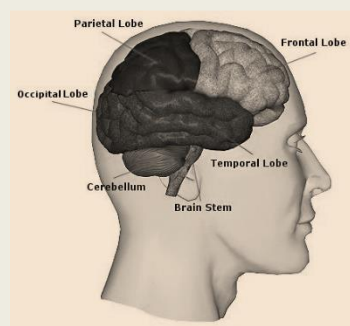
Dr. Somasekhar, Former Principal, A S M college for Womens, Ballari

EEG, an acronym for electroencephalogram, is the non-invasive technique of recording fluctuating electrical activity in the brain (brain wave) associated with emotions, behaviour and thinking. It is a useful tool in modern medical and psychological practices that allows clinicians to describe and diagnose various conditions and diseases related to the brain. If an individual goes to get an EEG the doctor will look at the waveform patterns to determine how different stimuli affect the brain. The year 2024 happens to be centenary year of the first recording of electrical activity within human brain by German psychiatrist Hans Berger. EEG has now become an indispensable tool in neurophysiology.

Hans Berger

EEG had its origin with the discovery of recordable electric potentials from activated nerves and muscles of animals and in the last quarter of the 19th century, from the cerebral cortex of animals. Hans Berger recorded potentials from the" scalp of patients with skull defects "and a few years later with more sensitive instruments from "intact subjects (those without defects)". Berger 's findings were independently confirmed in early 1934 by lord Adrian in England and Hallowell Davis at Harvard, USA.

Early Life and Education of Hans Berger



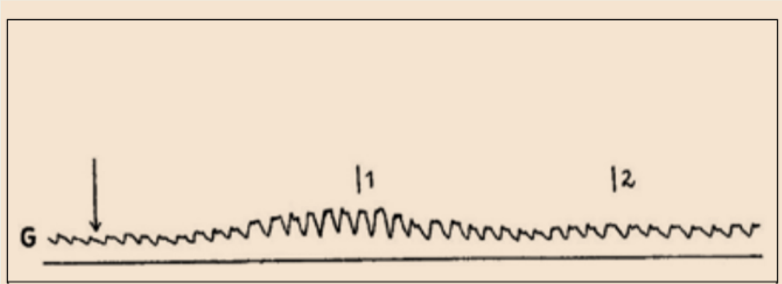
Hans Berger (1873-1941) was born in Neuses, Coburg, Germany on 21st May 1873. His father, Heinrich Berger was a practising physician and his mother Anna Rupel Berger a homemaker. On completion of secondary education in Casimirianum, in 1892, he enrolled as a mathematics and astronomy student at Friedrich Schiller University of Jena with the intention of becoming an astronomer. After one semester he discontinued the studies and enrolled for a year of service in German army. In the spring of 1893, just before his 20th birth day, during training, his horse suddenly lost balance and stumbled. Both he and his horse were thrown down an incline to fall beneath the rumblings of wheels of a large artillery piece drawn by six dray horses. The driver of the artillery battery, being alert, halted the horses and saved Berger from being crushed to death. As a strange coincidence his sister, sensing some danger for Berger, at home many miles away suddenly wake up in the night, is agitated and insisted their father to telegram Berger and enquire about his well-being. She told her parents ‘She knew with certainty’ Hans had suffered a deadly accident. On knowing this Berger believed this was a case of “spontaneous telepathy”, where in, at a time of mortal danger, he transmitted his thoughts to his sister, who was particularly close to him, acted as the receiver. This incident deeply affected Berger and made him curious about the possibility of telepathy or some form of communication between mind and brain that could occur without physical contact.

In the third millennium, however, skepticism may arise about Berger’s motivation for studying telepathy, as conclusive results were not obtained. Nevertheless, the peculiar notion of studying telepathy must be understood within the cultural milieu of the mid-nineteenth to mid-twentieth century, particularly in the midst of the telecommunications revolution: Maxwell’s seminal work on unification of electricity and magnetism in 1864, Hertz’s demonstration of electromagnetic waves in 1887, Marconi’s telegraph patent in 1897 and the first transoceanic transmission of radio signal in 1902. These developments solidified the understanding that ‘electric and magnetic phenomena combined’ formed the basis for long distance signal transmission. At the same time, it became known to him that animal exhibited electrical activity, starting from Galvani’s studies in late eighteenth century and later by experts from Europe. It is possible, Berger may have been inspired by the emerging knowledge of that period to entertain the revolutionary hypothesis of long- range thought transmission, considering telepathy somehow to be mediated by electrical energy in the brain. Berger embraced a psychophysical model based on the principle of energy conservation proposed by Helmholtz and Lehman. This model proposes an interaction between physical and mental phenomena, suggesting that the latter are out comes of the energetic transformations of the former. The model also proposes that, the chemical energy associated with any change in mental state in the brain undergoes conversion into three primary forms within the brain: heat, electricity and p-energy, the energy associated with specific mental states – thoughts, feelings and emotions. He believed that careful measurement of cerebral energetics would help in acquiring evidence for paranormal phenomenon such as telepathy.

On completion of his military service and obsessed by the idea of how his mind could have carried a signal to his sister, Berger switched his study from mathematics to medicine with a speciality in neuropsychiatry ,studying first in Wurzburg, then in Munich, Kiel and Jena universities with sole aim of discovering the physiological basis of this psychic energy transfer with the central theme “ the search for the correlation between objective activity in the brain and subjective psychic manifestations”. After obtaining his doctorate degree in medicine in 1897, he took position as a junior staff member at the psychiatric clinic of the University of Jena. He remained there for 41 years until his retirement in 1938 at the age of

65, having served as Dean of the Medical School, Rector of the University, and finally Director of the hospital.

Earlier works

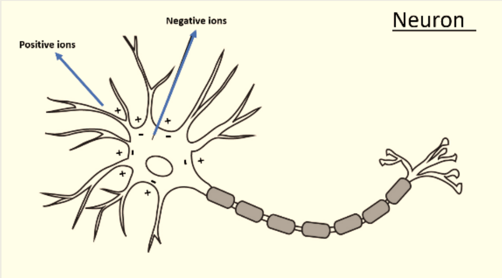


Change in the Base Line Due to Increase in Temperature of the Brain

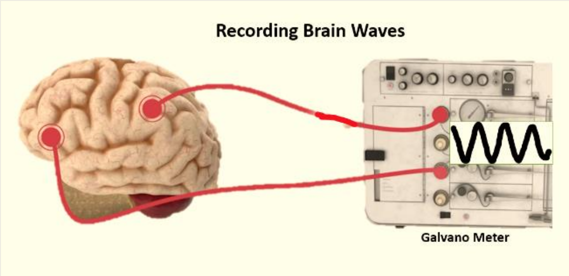
At the onset of his scientific career Berger attempted to study human mental function through measuring brain temperature, pressure and cerebral blood flow in relation to mental states. He speculated that changes in cerebral activity, such as intense thought or emotion, could influence local heat production in the brain. He had strong belief that a change in mental state must be associated with certain energy (psychic energy)that manifests in the form of thermal energy(which causes local heating resulting in increase in temperature) and electrical energy .He measured brain pressure using experimental methods (using plethysmograph).He also measured intracerebral temperature changes during neurological procedures in awake and locally anaesthetised patients and sought to identify biochemical alterations accompanying mental activity and consciousness. These studies were a broader attempt to establish a physiological basis for mental processes. Though his work on brain temperature and pressure was pioneering for its time, it did not yield conclusive results. He then turned his attention to studying “brain electrical activity “.

Berger was aware of the reported works of several European researchers in England, Poland, Ukraine and Germany on electrical activity of animal brains.

Origin of electrical activity in brain and brain waves

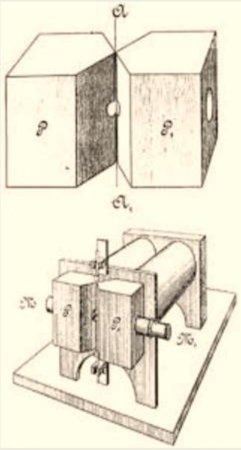


For most of the cells in human body there is always a potential difference across the cell membrane, called membrane potential (also called rest potential)due to distribution of excess positive Na ions outside the cell and a high concentration of negatively charged chloride ions (as well as small number of K^+ inside the cell), with the inside of the cell being more negatively charged relative to the outside. Human brain has billions of such cells called neurons. Each neuron with a membrane potential of -60 to -90 mv acts as an



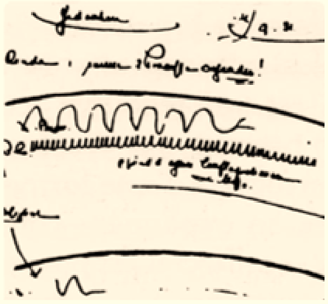
electrical cell and is connected to thousands of nearby neurons. Communication happens between them through small currents that travel along the neurons throughout the enormous networks of brain circuits. Any change in the membrane potential caused by an act (external or from within the brain) is transmitted as electrical signal (action potential) across the cell to the nearby cell and so on. Thus, the neurons by firing action potential, are in constant communication. These neurons firing electric potentials, generate electric field all around the brain. The distribution of this field is different for different regions of the brain. The brain is thus surrounded by a non-uniform electric field. Suppose we take two points on the scalp in any brain region ,one can measure a pd of about 40 to 90 μv. This pd, however, is not a constant but fluctuates due to different regions of the brain being active at different times influenced by brain's state, external stimuli and biophysical processes that generate electrical signals. These variations in electric potential difference form a pattern termed "brain waves" that provide valuable information about brain function and metal state.

Works on human brain


String Galvanometer

In1902, Berger could reproduce electrical signals from the cortical surface of a dog, as was reported earlier by Adolf Beck and Richard Caton. Berger's main interest was to evoke fluctuations of electrical currents in human brain to an external stimulus. The available technology was hardly conducive for such electro physiological research. The electrophysiologists were restricted to the use of "string galvanometer", most frequently used in clinical settings to record electrocardiogram. The devise uses a quartz conducting fibre stretched tightly between two fixed points. The fibre with a small mirror strip attached to it, rests in a strong magnetic field. A narrow beam of light reflected from the mirror is made to fall on a photographic paper. When the brain current passes through the fibre it is pulled to one side by Lorentz force. If the current is varying the fibre oscillates and the beam of light reflected from the mirror on to the photo paper traces a wave pattern as the photo paper slides down at a constant speed. The oscillations of the current thus recorded on a photographic paper is representative of the brain current fluctuations constituting a "brain wave". But these currents were very very small and disappointing. (In early 1910s, recurrent episodes of depression, his marriage to the baroness Ursula Von Bulow- a technician in the psychiatric clinic- in 1911, his appointment as chief physician of the university clinics in 1912 and the outbreak of world war1 in 1914 left Berger with little to no time to dedicate to his research on cerebral energetics. During world war1, he was deployed to serve as neuropsychiatrist at the western front Retha, which gave him time to study English and human sciences particularly philosophy and make plans for his research after-war.)

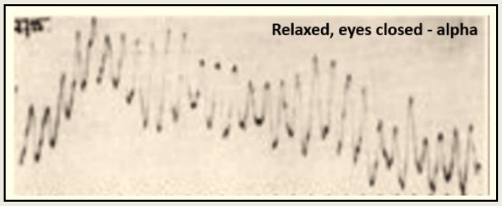
First recording of human brain wave

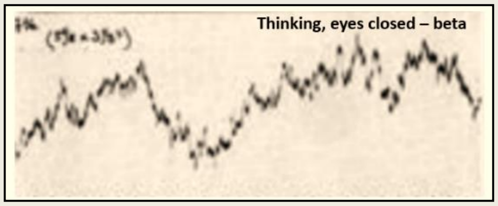


First brain EEG recording of Human Brain activity made by Hans burger on July 6, 1924 .

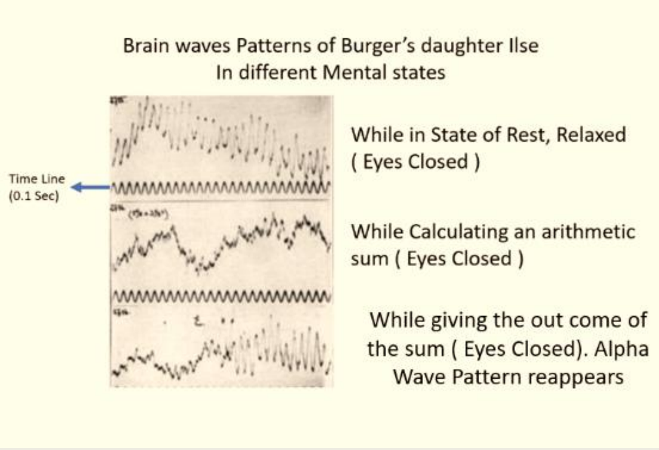
Berger's first efforts of recording the electrical activity of the brain were a complete disaster to begin with and that's why in 1920 Berger took up yet another physiological technique "electrical stimulation of the brain" by applying weak external electrical voltages on the surface of the brain in the absence of the stimulus. Once, after an electrical stimulation session Berger decided to switch the electrodes from the electrical stimulator to the modified galvanometer, generally used to measure electrocardiogram recordings and there was his first hint of success when minute, continuous oscillations appeared in the galvanometer. The measured result was blurred and noisy, when recorded on a paper, and for many people meaningless. But it was the starting point of encephalography. After this success Berger improved his method trying different electrodes and galvanometer. In 1924, the idea occurred to him to attempt electrical recordings from patients who had undergone palliative trepanation. He reasoned that since there was a thin sheath of tissue covering the trepidation, in such site of skull defects, the problem of measuring electrical activity might be simplified. **Finally, on July 6, 1924 he was able to observe and record EEG from a seventeen-year-old boy who had a trepanation (a surgical procedure that involved drilling or scraping a hole into the human skull) undergoing surgery for a suspected brain tumour a couple of years ago, and the electrodes were placed directly on frontal parietal surface of the cortex that was exposed.** Berger detected electrical signals from this part of the head with electrodes placed on the cortex of the wound site. Though he failed to notice any current in his initial attempts he obtained fluctuations of high magnification only when the electrodes were positioned 4.5cm apart. He wrote in his notes that consistent electric currents could likely be drawn from the intact cerebral cortex in humans i.e. healthy individuals, just as seen in dogs, rabbits and monkeys as reported earlier. This heralded, for the first time in history, the presence of electrical activity recorded from human brain and laid the foundation for the field of EEG and our understanding of brain function. Berger continued to record from human subjects but often found it difficult to make successful recordings. He continued to refine his methods and validate his results over the following years. In 1926, he procured Seaman's double coil galvanometer providing a sensitivity of recording of about 7 1/2 times that of string galvanometer. Finally in 1929, after recording hundreds of wave forms under similar conditions of mental state, Berger published his first report titled “On the electroencephalogram of humans “.

- This recording, on a photographic paper, primarily displayed wave pattern of frequency in the range 8-13 Hz, with some occasional higher frequency waves, demonstrating the rhythmic electrical oscillations of the brain regions. The low frequency waves, he called them alpha waves, were visible as smooth, regular, sinusoidal oscillations. The waves were dominant when the subject was relaxed with eyes closed and they disappeared or reduced in amplitude when the subject opened their eyes or became mentally active.

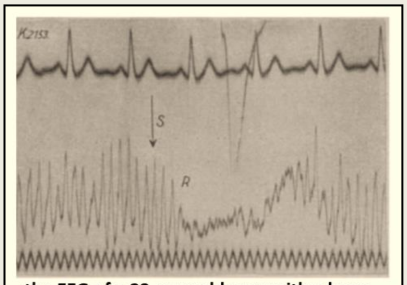




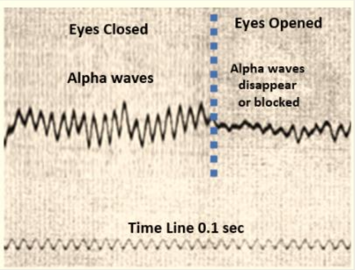
- Some higher frequency waves that he had recorded, he called beta waves, of frequency 13-30Hz were observed when the subject engaged in mental activity. The amplitude ranged between 20-100 μv, typical of brain waves.
- The rhythm disappeared when the subjects opened their eyes or changed from alpha to beta when they performed mental tasks like arithmetic calculations, a phenomenon known as alpha blocking or Berger effect.
- This recording was significant because it was the first scientifically documented EEG of a human brain as proof of Berger’s hypothesis that “brain generates measurable electrical activity characteristic of mental state” and helped Berger identify alpha rhythm.
- This recording was a breakthrough in neuroscience as it demonstrated a) the potential for non-invasive measurement of brain activity b) the relationship between mental states and brain wave patterns and laid the foundation for future classification of brain waves thus paving the way for modern neurophysiology and brain research.



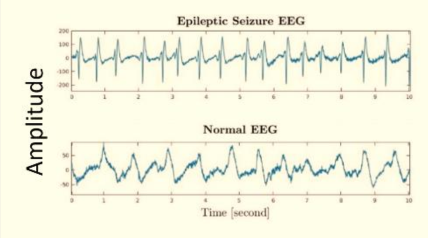
Between 1929 and 1938 he published 14 more papers each with the same title but with numericals, first report, second report. During this intervening period he took 73 scalp recordings from his son Klaus ,who was between 15-17 years during the studies. He recorded the signals from the brain of his daughter Ilse first in relaxed state with eyes closed and then in a state of performing arithmetic. He notes that Klaus’ hair was "cut as short as possible" whenever investigations were carried out. He also selected a series of volunteers for examination, taking into account the preferability of baldness for achieving beautiful recordings. He took simultaneous recordings of EEG and mechanical oscillations from Klaus' scalp using a pulse phone. This he did to ensure that EEG were not associated with the pulsatile oscillations of the scalp. He also took 56 traces from himself. The recordings were done with subjects in different mental states such as wake state, relaxed state, state of thinking, deep thinking, changing from relaxed to thinking state, eyes closed and eyes opened. In one case he records change in wave pattern by pricking the finger of a subject with a sharp pin. By 1931, he had gathered 1133 records from 76 people establishing a normalisation for alpha and beta waves in terms of frequency and amplitude. He had also recorded the brain signals of patients with seizures, epilepsy, drug addiction and dementia. After working on the results of his studies and analysing the wave patterns for several years, he compiled his work in a monograph "Nova Actinal Leopoldina" published in 1938. This monograph comprised,



the EEG of a 33-year-old man with a large gap in the skull. You can see the alpha wave began with. A needle was briefly inserted in the left index finger (S). The wave patterns changes from R in the Figure. The alpha wave pattern reappearance after the needle removed.



- description of normal EEG of the adult with his α and βwave
- the blocking of alpha waves in response to eye opening or sensory stimuli,
- Characterising brain waves in terms of their frequency (α, β,),
- the EEG across age groups (new born, children and elderly),isoelectric EEG in brain death (a flat brain wave indicating absence of any electric activity),the effect of narcotics (slowing of α and β activity) and hyperventilation on EEG (increase in β wave activity and decrease in α wave activity) and EEG changes associated with different pathological states,
- intracranial haemorrhage reflected by slowing of α and β activity with disrupted normal rhythm,
- dementia - decreased alpha wave and beta wave activity
- interictal epileptiform activity- brief and abnormal spikes single or in bursts and seizures- rapid recruitment of high amplitude waves with spikes. With certain exceptions almost all the epilepsy patients showed the characteristic EEG alterations during epileptic seizures.



Validation and Recognition

Despite initial scepticism from the scientific community in German circles, Berger's findings were validated and gained recognition in the 1930s. In 1934 in Cambridge, England, Nobel laureate Lord E.D. Adrian and B H C Mathews confirmed Berger's findings. Even Adrian called alpha waves as "Berger waves". In the same year Herbert H Jasper working with Carmichael was the first from North America to confirm Berger's reports on human EEG. In 1935 Gibbs, David and others detected interictal epileptic forms and 3 Hz spikes during clinical seizures. Fischer and Loven back reported first epileptic form spikes. Berger's work marked a critical turning point, as it provided a measurable and objective method for studying brain activity, bridging the gap between psychology and physiology. In 1937 Berger was invited to speak about his discoveries at the International Psychological Congress in Paris and at the centenary of Galvani's birth in Bologna. In 1939 he was invited to give a series of lectures in the United States, which were hampered by the outbreak of war. EEG became a standard diagnostic tool first in US, England, and France, and then worldwide. Berger's scientific endeavors made him: a member of German Academy of natural Sciences Leopoldina, Honorary member of American neurological Association, Honorary member American Psychiatric Association and Corresponding member Royal Society of medicine , London. It is said that ,for the development of electroencephalography and pioneering neural recordings he was nominated six times for the Nobel Prize , during 1940s and 1950s. Berger's clinical-scientific legacy, now comprehensively recognised, extended and improved, firmly places him among the pioneers of neurological disciplines. In Honor of Berger an asteroid is named after him and an Italian stamp on epilepsy features the human alpha EEG signal that he first recorded.

Stamp Realized in Italy

Tragic End

In 1935 Berger was forced to abandon his research on EEG by Nazi party but kept his publications with notes and the material gathered. In 1938 he was not reappointed by Nazi Regime to his position as Hospital director, eventually leaving Berger to scientific ostracism. On June 1st ,1941 during a severe episode of depression , after long process of decay due to heart failure and skin infection , Berger committed suicide by hanging. He was survived by his wife, son and daughter.

Conclusions: Hans Berger's discovery and characterisation of brain waves were monumental achievements in the history of science. His pioneering efforts not only demonstrated the existence of electrical activity in the brain but also provided the foundation for modern neurophysiology and the development of EEG technology. Despite initial skepticism ,Berger's work has had a lasting impact on medicine, research and our understanding of human mind. Today, the legacy of Hans Berger lives on in countless applications of EEG, from diagnosing epilepsy to advancing brain- computer interfaces. His determination, curiosity and meticulous approach to sciences serve as an enduring inspiration, reminding us of the profound insights that can emerge from a relentless pursuit of knowledge.

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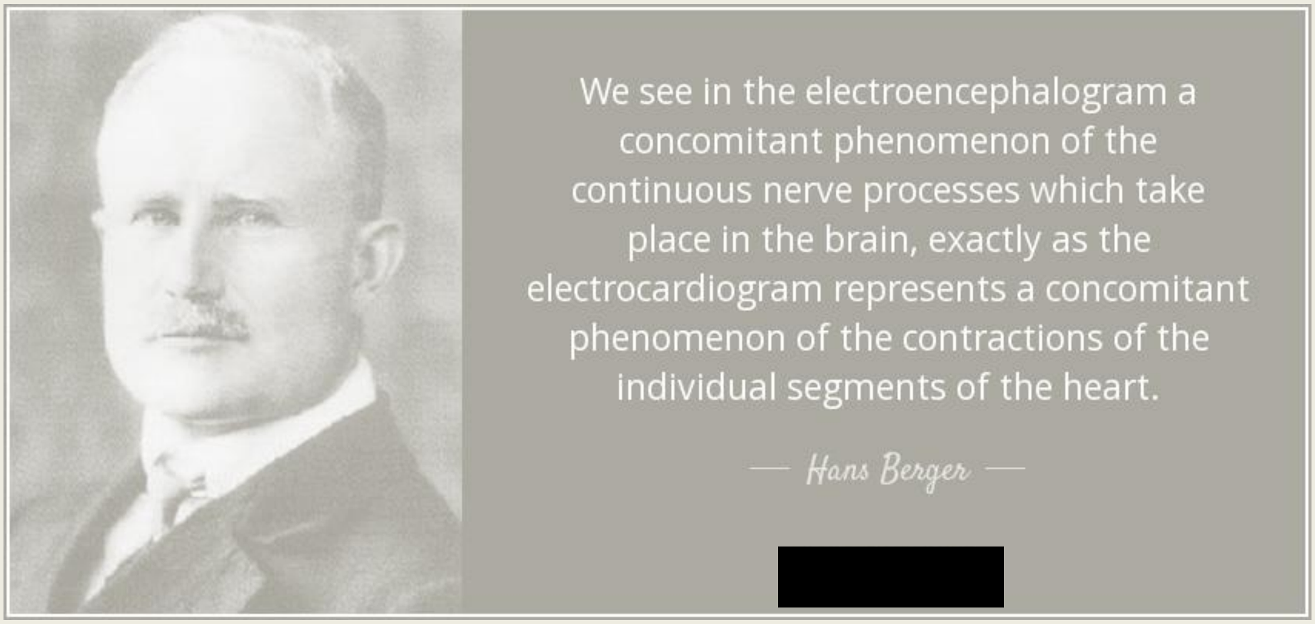


ಸೂಪರ್ನೋವಾ

ಡಾ. ಶಾರದಾ ನಾಗಭೂಷಣ, Professor of physics (retd), APS College, Bengaluru

ಚಿತ್ರ 1 ಸೂಪರ್ನೋವಾ

ಆಗಸದಲ್ಲಿ ದೈತ್ಯನಕ್ಷತ್ರಗಳ ಅಂತಿಮಘಟ್ಟದಲ್ಲಿ ಸಂಭವಿಸುವ ಸ್ವಯಂವಿಧ್ವಂಸಕ ವಿದ್ಯಮಾನವೇ 'ಸೂಪರ್ನೋವಾ' (*Supernova*). ಕನ್ನಡದಲ್ಲಿ 'ಮಹಾನವ್ಯ' ಎನ್ನಬಹುದು. 1931ರಲ್ಲಿ ಡಾ. ವಾಲ್ಟರ್ ಬಾಡೆ ಮತ್ತು ಸ್ವಿಕಿ (*Walter Baade and Zwicky*) ಎಂಬ ಖಗೋಳವಿಜ್ಞಾನಿಗಳು 'ಸೂಪರ್ನೋವಾ' ಹೆಸರನ್ನು ಸೃಷ್ಟಿ ಮಾಡಿದರು. ಸೂಪರ್ನೋವಾ ಆಗುವ ಮುಂಚಿತವಾಗಿ ಆ ದೈತ್ಯನಕ್ಷತ್ರಗಳು ಮೂಲವಸ್ತುಗಳು, ವಿಕಿರಣ ಮತ್ತು ನ್ಯೂಟ್ರಿನೋಗಳ ಆಗರವಾಗಿದ್ದು, ಅದು ಸಂಭವಿಸಿದಾಗ ಅವುಗಳನ್ನೆಲ್ಲಾ ಅಂತರ ತಾರಾವಲಯದಲ್ಲಿ ಖಾಲಿಮಾಡಿ ಪ್ರಸರಣ ನಿಹಾರಿಕೆ (*Diffusion Nebula*) ಆಗಬಹುದು. ಅಲ್ಲಿಂದ ಮುಂದೆ ಒಂದು ಸಮಯದಲ್ಲಿ ನಕ್ಷತ್ರ ಮತ್ತು ಗ್ರಹಗಳಿಂದ ಕೂಡಿದ ನಕ್ಷತ್ರಮಂಡಲವಾಗಿಯೂ ರೂಪಿತಗೊಳ್ಳಬಹುದು. ಇಲ್ಲವೆ ಕುಸಿದು ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರ ಅಥವಾ ಕಪ್ಪು ರಂಧ್ರವಾಗಬಹುದು.

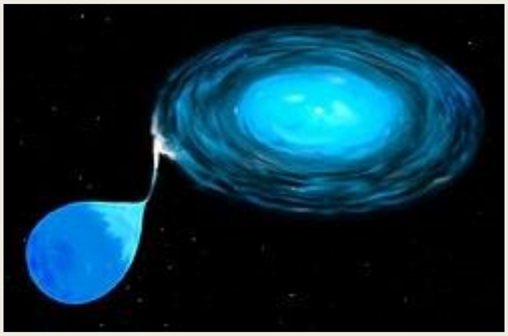
ವಿಶ್ವದಲ್ಲಿ ಪ್ರತಿ 10 ಸೆಕೆಂಡಿಗೆ ಒಂದು ಸೂಪರ್ನೋವಾ ಸಂಭವಿಸುತ್ತದೆಯೆಂದು ತಿಳಿದುಬಂದಿದೆ. ಇದು ಸಂಭವಿಸಿದಾಗ ಕೆಲವು ಸಮಯ ಇಡೀ ನಕ್ಷತ್ರಪುಂಜವೇ ಅತಿಯಾಗಿ ಪ್ರಕಾಶಿಸುತ್ತದೆ. ನಮ್ಮ ಸೂರ್ಯನಿಗಿಂತ ಅನೇಕ ಪಟ್ಟು ದೊಡ್ಡ ನಕ್ಷತ್ರಗಳ ಮಧ್ಯೆ ಇಂಧನ ಮುಗಿದು ಪರಮಾಣು ಸಮ್ಮಿಳನವಾಗದೆ ಕುಸಿದು ಸೂಪರ್ನೋವಾ ಆಗಿ ಸಿಡಿಯುತ್ತವೆ. ಇಲ್ಲವೆ ಕೆಲವು ಶ್ವೇತಕುಬ್ಜವು ತನ್ನ ಯುಗಳನಕ್ಷತ್ರದಿಂದ ದ್ರವ್ಯವನ್ನು ಹೀರಿಕೊಂಡ ಪರಿಣಾಮವಾಗಿ ಅದರ ದ್ರವ್ಯರಾಶಿಯು 1.44ಗಿಂತ ಹೆಚ್ಚಾದರೆ ಆ ಶ್ವೇತಕುಬ್ಜವು ಸೂಪರ್ನೋವಾ ಆಗಿ ಸಿಡಿಯುತ್ತದೆ. ಸೂಪರ್ನೋವಾ ಸಿಡಿತವು ಒಂದು ಸೆಕೆಂಡ್‌ನಲ್ಲಿ ಸಂಭವಿಸುವ ವಿದ್ಯಮಾನವಾದರೂ, ಅದು ಹಲವಾರು ವಾರಗಳಿಂದ ತಿಂಗಳುಗಳ ತನಕವೂ ವೀಕ್ಷಣೆಗೆ ಲಭ್ಯವಿರುತ್ತದೆ.

ಸೂಪರ್ನೋವ ವಿಧಗಳು: ಟೈಪ್1 ಮತ್ತು ಟೈಪ್2 ಎಂಬ ಎರಡು ವಿಧಗಳಿವೆ.

1 … ಟೈಪ್1 ಸೂಪರ್ನೋವ

ಇದು ಬೇರೆ ವಿಧಕ್ಕಿಂತ ಹೆಚ್ಚಿನ ಪ್ರಕಾಶತೆಯನ್ನು ತೋರುತ್ತದೆ. ತಾನು ಹೊರಸೂಸುವ ವರ್ಣಪಟಲದಲ್ಲಿ ಜಲಜನಕದ ಗೆರೆ ಇರುವುದಿಲ್ಲ. ಟೈಪ್2ರ ಎರಡರಷ್ಟು ವಿಸ್ತಾರಗೊಳ್ಳುತ್ತವೆ. ಇದರಲ್ಲಿ **ಟೈಪ್1ಎ, ಟೈಪ್ಬಿ ಮತ್ತು ಟೈಪ್1ಸಿ** ಎಂಬ ಮೂರು ವಿಧಗಳನ್ನು ಕಾಣಬಹುದು.

ಟೈಪ್ 1ಎ



ಚಿತ್ರ 2 ದೈತ್ಯ ನಕ್ಷತ್ರ ಮತ್ತು ಶ್ವೇತಕುಬ್ಜಗಳ ಯುಗಳ ವ್ಯವಸ್ಥೆ

ಇವು ಯುಗಳ ನಕ್ಷತ್ರಗಳಿಂದ ರೂಪುಗೊಳ್ಳುತ್ತವೆ. ಯುಗಳದಲ್ಲಿ ಒಂದು ದೈತ್ಯ ನಕ್ಷತ್ರವಾಗಿದ್ದು ಮತ್ತೊಂದು ಶ್ವೇತಕುಬ್ಜವಾಗಿರುತ್ತದೆ (ಚಿತ್ರ 2). ಅತೀವ ಸಾಂದ್ರತೆಯನ್ನು ಹೊಂದಿರುವ ಶ್ವೇತಕುಬ್ಜವು ದೈತ್ಯ ನಕ್ಷತ್ರದಿಂದ ದ್ರವ್ಯರಾಶಿಯನ್ನು ತನ್ನೆಡೆಗೆ ಎಳೆದುಕೊಳ್ಳುತ್ತಾಬರುತ್ತದೆ. ಅದು ಚಂದ್ರಶೇಖರ್ ಲಿಮಿಟ್ ಆದ ಸೂರ್ಯನ ದ್ರವ್ಯರಾಶಿಯ 1.44ಅನ್ನು ದಾಟಿದನಂತರ ಆ ಶ್ವೇತಕುಬ್ಜದಲ್ಲಿ ಥರ್ಮೋನ್ಯೂಕ್ಲಿಯರ್ ಪ್ರತಿಕ್ರಿಯೆಯಿಂದ **ಸೂಪರ್ನೋವ** ಆಗಿ ಶಾಖ ಮತ್ತು ಬೆಳಕನ್ನು ಬಿಡುಗಡೆ ಮಾಡುತ್ತಾ ಸಿಡಿಯುತ್ತದೆ. ಟೈಪ್ 1ಎ ಸೂಪರ್ನೋವದಲ್ಲಿ ಕಬ್ಬಿಣವೇ ಪ್ರಧಾನವಾಗಿರುತ್ತದೆ. ಈ ಅತಿ ಹೆಚ್ಚಿನ ಶಾಖ ಮತ್ತು ಥರ್ಮೋನ್ಯೂಕ್ಲಿಯರ್ ಪ್ರತಿಕ್ರಿಯೆಯಿಂದ ಅದರ ದ್ರವ್ಯದಲ್ಲಿ ಭಾರವಾದ ರೇಡಿಯೋ ಆಕ್ಟೀವ್ ಮೂಲವಸ್ತುಗಳೂ ರೂಪುಗೊಳ್ಳುತ್ತವೆ. ಕೆಲವು ಸೂಪರ್ನೋವಗಳು ಅಂತರತಾರಾವಲಯದಲ್ಲಿ ಹೊಸ ನಕ್ಷತ್ರ ಮಂಡಲಕ್ಕೂ ಕಾರಣವಾಗಬಹುದು. **ಟೈಪ್ 1ಎ ಸೂಪರ್ನೋವ–ಸ್ಟಾಂಡರ್ಡ್ ಕ್ಯಾಂಡಲ್**

ದೂರದ ನಕ್ಷತ್ರಗಳ ವರ್ಣಪಟಲದ ಕೆಂಪು ಪಲ್ಲಟದಲ್ಲಿ ವಿಶ್ವವು ಎಷ್ಟು ಪ್ರಮಾಣದಲ್ಲಿ ದೂರಸರಿಯುತ್ತಾ ಹಿಗ್ಗುತ್ತಿದೆ ಎಂಬುದು ತಿಳಿದುಬರುತ್ತದೆ.

ಟೈಪ್ 1ಎ ಸೂಪರ್ನೋವ ಅತಿ ಹೆಚ್ಚಿನ ಪ್ರಕಾಶತೆಯನ್ನು ಹೊರಹೊಮ್ಮುವುದರಿಂದ, ಈ ಪ್ರಕಾಶತೆಯನ್ನು ಅಳೆಯುವುದರ ಮೂಲಕ ವಿಶ್ವವು ವಿಸ್ತಾರವಾಗುತ್ತಿರುವ ವೇಗವನ್ನು ತಿಳಿಯಲು ಸಹಕಾರಿಯಾಗಿದೆ. ಅದರ ಪ್ರಕಾರ ಈಗ ವಿಶ್ವವು ವಿಕಾಸವಾಗುತ್ತಿರುವ ವೇಗವು ಹೆಚ್ಚಾಗುತ್ತಿದೆಯೆಂದೂ ತಿಳಿದುಬಂದಿದೆ.

ಚಿತ್ರ 3 ಕೆಂಪು ಪಲ್ಲಟ ಮತ್ತು ನೀಲಿ ಪಲ್ಲಟ

ಖಗೋಳವಿಜ್ಞಾನಿಗಳ ಪ್ರಕಾರ ಟೈಪ್ 1ಎ ಸೂಪರ್ನೋವ–'ಸ್ಟಾಂಡರ್ಡ್ ಕ್ಯಾಂಡಲ್'ಆಗಿ ವಿಶ್ವವಿಸ್ತಾರವನ್ನು ಅಳೆಯುವ ಮಾನದಂಡವಾಗಿದೆ. ಭೂಮಿಯಲ್ಲಿ ದೂರದರ್ಶಕದ ಮೂಲಕ ದೂರದ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ ಸಂಭವಿಸಿದ ಟೈಪ್ 1ಎ ಸೂಪರ್ನೋವಾದ ಬೆಳಕಿನ ವರ್ಣಪಟಲವನ್ನು ವೀಕ್ಷಣೆ ಮಾಡಿದಾಗ ಅದರ ಹೀರಿಕೊಳ್ಳುವ ವರ್ಣಪಟಲವು (ಚಿತ್ರದಲ್ಲಿ ಕಪ್ಪು ಗೆರೆಗಳು) ಕೆಂಪು ಬಣ್ಣದೆಡೆಗೆ ಸ್ಥಳಾಂತರವಾಗಿದೆ ಎಂಬುದು ತಿಳಿಯುತ್ತದೆ (ಚಿತ್ರ 3). ಇದಕ್ಕೆ ಕೆಂಪು ಪಲ್ಲಟ($red\ shift$)ವೆನ್ನುವರು. ಇದರಿಂದ ವಿಶ್ವವು ವಿಸ್ತಾರವಾಗುತ್ತಿದೆಯೆಂದು ಮತ್ತು ಅದರ ವೇಗೋತ್ಕರ್ಷವನ್ನೂ ತಿಳಿಯಬಹುದು. ಯಾವುದಾದರೂ ಬೆಳಕಿನ ಆಕರವು ಭೂಮಿಯೆಡೆಗೆ ಚಲಿಸುತ್ತಿದ್ದರೆ ನೀಲಿ ಪಲ್ಲಟ ($blue\ shift$)ವೇರ್ಪಡುತ್ತದೆ.

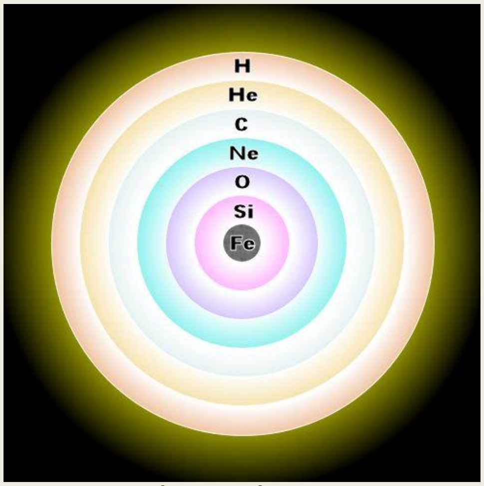
ಅನೇಕ ಜ್ಯೋತಿರ್ವರ್ಷ (ಒಂದು ಜ್ಯೋತಿರ್ವರ್ಷ=ಬೆಳಕು ಒಂದುವರ್ಷದಲ್ಲಿ ಚಲಿಸುವ ದೂರ=6×10^{12}ಕಿ.ಮೀ.)ದೂರದಿಂದ ಪ್ರಕಾಶಿಸುತ್ತಿರುವ ಸೂಪರ್ನೋವಾದ ಬೆಳಕಿನ ವರ್ಣಪಟಲವನ್ನು ಅಧ್ಯಯನ ಮಾಡಿ ಅದು

ಎಷ್ಟು ‘ಕೆಂಪು ಪಲ್ಲಟ($Red\ shift$)ವಾಗಿದೆಯೆಂದು ಅಳೆದು ಅದನ್ನು ಪ್ರಯೋಗಾಲಯದ ವರ್ಣಪಟಲದೊಡನೆ ಹೋಲಿಸುವುದರಿಂದ, ಸೂಪರ್ನೋವಾ ಸಂಭವಿಸಿದಂದಿನಿಂದ ವಿಶ್ವವು ಎಷ್ಟು ವಿಸ್ತಾರವಾಗಿದೆ ಮತ್ತು ವೇಗೋತ್ಕರ್ಷವನ್ನು ಪಡೆದಿದೆಯೆಂದು ಲೆಕ್ಕ ಹಾಕಬಹುದು.

ಡಾಪ್ಲಾರ್ ಎಂಬ ವಿಜ್ಞಾನಿಯು ಮೊಟ್ಟಮೊದಲು **ಶಬ್ದದ ಮೂಲವು** ನಮ್ಮಿಂದ ದೂರ ಸರಿಯುತ್ತಿದ್ದರೆ ಅದರ ತರಂಗಾತರವು ಹೆಚ್ಚು ತರಂಗಾಂತರದೆಡೆಗೆ ಸ್ಥಳಾಂತರವಾದಂತೆ ತೋರುತ್ತದೆ ಎಂದು ಪ್ರಯೋಗದ ಮೂಲಕ ತೋರಿಸಿದರು.

ಚಲಿಸುತ್ತಿರುವ **ಬೆಳಕಿನ ಮೂಲವು** ತನ್ನಲ್ಲಿರುವ ಮೂಲವಸ್ತುಗಳ ವರ್ಣಪಟಲವನ್ನು ಹೊರಸೂಸುತ್ತದೆಯಷ್ಟೆ. ೧೯೨೯ರಲ್ಲಿ ಖಗೋಳವಿಜ್ಞಾನಿ ಎಡ್ವಿನ್ ಹಬಲ್ ಈ ಬೆಳಕಿನ ಮೂಲವು ಭೂಮಿಯಿಂದ ದೂರ ಚಲಿಸುತ್ತಿದ್ದರೆ ಅದರ ವರ್ಣಪಟಲದ ಗೆರೆಗಳು ಕೆಂಪು ಬಣ್ಣದೆಡೆಗೆ (ಹೆಚ್ಚು ತರಂಗಾಂತರದೆಡೆಗೆ) ಸ್ಥಳಾಂತರವಾಗುತ್ತದೆ ಎಂದು ಸಂಶೋಧಿಸಿದರು. ಅಂದರೆ ಆ ಪ್ರಕಾಶದ ಬೆಳಕಿನ ಮೂಲವಾದ ಸೂಪರ್ನೋವಾ ನಮ್ಮಿಂದ ದೂರ ಸರಿಯುತ್ತಿದೆ ಎಂದು ನಿರ್ಧಾರ. ಅಲ್ಲದೆ ಹಬಲ್ ವಿಶ್ವದ ರಚನೆಯನ್ನು ಕಂಡು ಹಿಡಿದು ಅದು ಅನೇಕ ಗ್ಯಾಲಾಕ್ಸಿಗಳಿಂದ ಕೂಡಿದ್ದು ಕಾಲಕಳೆದಂತೆ ಅದು ಒಂದಕ್ಕೊಂದು ದೂರವಾಗುತ್ತಾ ವಿಶ್ವವು ಹಿಗ್ಗುತ್ತಿದೆಯೆಂದು ಮೊದಲು ಋಜುವಾತು ಪಡಿಸಿದರು. ಗ್ಯಾಲಾಕ್ಸಿಯ ಸೂಪರ್ನೋವಾದ ಬೆಳಕಿನಲ್ಲಿ ಸಂಭವಿಸುವ ಈ ಕೆಂಪು ಪಲ್ಲಟದ ಪ್ರಮಾಣವು ಅದು ಭೂಮಿಯಿಂದ ಇರುವ ದೂರವನ್ನು ಅವಲಂಬಿಸಿರುತ್ತದೆ, ಅಂದರೆ ನಮ್ಮಿಂದ ದೂರವಿರುವ ಗ್ಯಾಲಾಕ್ಸಿಯು ವೇಗೋತ್ಕರ್ಷ ಪಡೆಯುತ್ತದೆ ಎಂದು ಮೊದಲು ತೋರಿಸಿದರು. ಗ್ಯಾಲಾಕ್ಸಿಯ ಕೆಂಪು ಪಲ್ಲಟವನ್ನು ಅಳೆಯುವುದರಿಂದ ಗ್ಯಾಲಾಕ್ಸಿಯು ಎಷ್ಟು ವೇಗವಾಗಿ ನಮ್ಮಿಂದ ದೂರಸರಿಯುತ್ತಿದೆ ಎಂಬುದನ್ನು ಲೆಕ್ಕಹಾಕುತ್ತಾರೆ. ಇದು ಈ ಶತಮಾನದ ಖಗೋಳವಿಜ್ಞಾನದ ಮಹತ್ತರ ಸಂಶೋಧನೆಯಾಗಿದ್ದು, 1927ರಲ್ಲಿ ಜಾರ್ಜ್ ಲಿಮಟೈರ್ ಪ್ರಸ್ತಾಪಿಸಿದ ಸಿದ್ಧಾಂತವನ್ನು ಪ್ರಯೋಗಾತ್ಮಕವಾಗಿ ಬೆಂಬಲಿಸಿತು. ಐನ್‌ಸ್ಟಿನ್ ತಮ್ಮ ಸಿದ್ಧಾಂತವಾದ, ಸ್ಥಾಯಿ ವಿಶ್ವಕ್ಕೆ ಬದಲಾಗಿ ವಿಸ್ತಾರವಾಗುತ್ತಿರುವ ವಿಶ್ವದ ಸಿದ್ಧಾಂತವು ಪ್ರಯೋಗಾತ್ಮಕವಾಗಿ ಋಜುವಾತಾಗಿದ್ದನ್ನು ಸಂತೋಷದಿಂದ ಸ್ವೀಕರಿಸಿ ‘ತಮ್ಮ ಜೀವಮಾನದ ದೊಡ್ಡ ಪ್ರಮಾದ’ ($greatest\ blunder$)ಎಂದು ಒಪ್ಪಿಕೊಂಡರು.

ಟೈಪ್ 1ಬಿ ಮತ್ತು ಟೈಪ್ 1ಸಿ ಸೂಪರ್ನೋವ

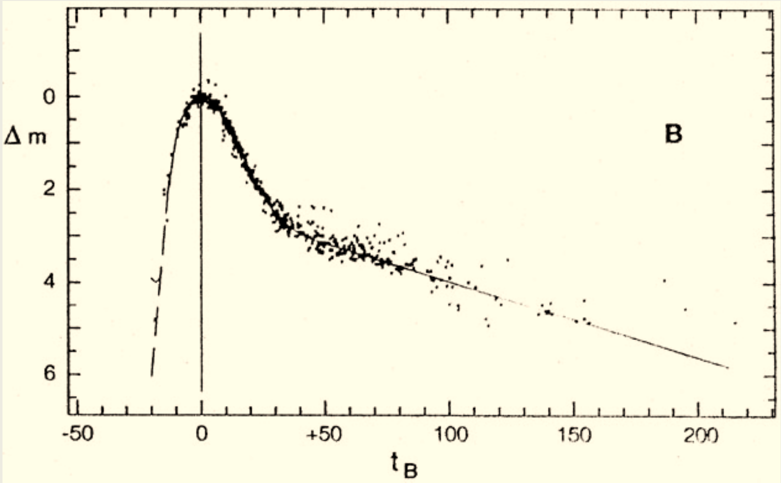


ಚಿತ್ರ 4 ಸೂಪರ್ನೋವಕ್ಕೆ ಮುಂಚಿತವಾಗಿ ಮೂಲವಸ್ತುಗಳ ಈರುಳ್ಳಿಯಾಕಾರದ ಪದರ

ಈ ಬಗೆಯ ಸೂಪರ್ನೋವಾಗಳು ದೈತ್ಯ ನಕ್ಷತ್ರಗಳ ಕುಸಿತದಿಂದ ಉಂಟಾಗುತ್ತವೆ. ಇಲ್ಲಿ ಸೂಪರ್ನೋವಾ ಸಂಭವಿಸುವ ಮುಂಚಿತವಾಗಿ ಅವುಗಳಲ್ಲಿರುವ ಮೂಲವಸ್ತುಗಳು ಈರುಳ್ಳಿಯಾಕಾರದಲ್ಲಿ ತಮ್ಮನ್ನು ಸಂಘಟಿಸಿಕೊಳ್ಳುತ್ತವೆ (ಚಿತ್ರ 4). ವರ್ಣಪಟಲಗಳಲ್ಲಿ ಕ್ರಮವಾಗಿ ಜಲಜನಕ, ಹೀಲಿಯಂ, ಇಂಗಾಲ, ನಿಯಾನ್, ಆಮ್ಲಜನಕ ಮುಂತಾದ ಗೆರೆಗಳು ಕಾಣಿಸಿಕೊಳ್ಳುತ್ತವೆ. ಈ ಬಗೆಯ ಸೂಪರ್ನೋವಗಳ ನಕ್ಷತ್ರಗಳು ಅಂತರತಾರಾವಲಯದಲ್ಲಿ ಬೀಸುವ ಬಲವಾದ ಗಾಳಿಯಿಂದ ಅವುಗಳ ಹೊರ ಕವಚವಾದ ಟೈಪ್ 1ಬಿಯಲ್ಲಿ ಜಲಜನಕ ಮತ್ತು ಟೈಪ್ 1ಸಿಯಲ್ಲಿ ಜಲಜನಕ ಮತ್ತು ಹೀಲಿಯಂನ ಪದರಗಳು ಕಳಚಿಕೊಳ್ಳುತ್ತವೆ. ಕೆಲವು ಬಾರಿ ಟೈಪ್೧ಸಿ ಸೂಪರ್ನೋವದಲ್ಲಿ ಗಾಮಾ ರೇ ಬರ್ಸ್ಟ್ ಸಹ ಆಗುತ್ತದೆಯೆಂದು ಅದರ ವರ್ಣಪಟಲ ಅಧ್ಯಯನದಿಂದ ತಿಳಿದುಬಂದಿದೆ. ಈ ಟೈಪ್ 1ಬಿ ಮತ್ತು ಟೈಪ್ 1ಸಿ ಸೂಪರ್ನೋವಗಳು

ಸಂಭವಿಸುವುದು ಅಪರೂಪವೆಂದು ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಅಭಿಪ್ರಾಯ ಪಡುತ್ತಾರೆ. ಅವುಗಳು ಸಾಮಾನ್ಯವಾಗಿ ಹೊಸ ನಕ್ಷತ್ರಗಳು ರೂಪುಗೊಳ್ಳುವ ತಾಣದಲ್ಲಿ ಸಂಭವಿಸುತ್ತವೆ. 1994ರಲ್ಲಿ ವಿರ್ಲ್‌ಪೂಲ್ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ $SN1994I$ ಎಂಬ ಟೈಪ್1ಸಿ ಸೂಪರ್ನೋವವನ್ನು ಕಂಡುಹಿಡಿಯಲಾಯಿತು. ಅದು ತನ್ನ ಹೊರಕವಚವಾದ ಜಲಜನಕ ಮತ್ತು ಹೀಲಿಯಂಅನ್ನು ಹೊರಹಾಕುತ್ತಾ ಪ್ರಕಾಶಮಾನವಾದ ವಿಕಿರಣವನ್ನು ಹೊರಸೂಸುತ್ತಾ ಕೆಲವು ತಿಂಗಳನಂತರ ಮಸುಕಾಯಿತು ಎಂದು ತಿಳಿದುಬಂದಿದೆ.

ಲೈಟ್ ಕರ್ವ್ಸ್: ಖಗೋಳ ಕಾಯಗಳಲ್ಲಿ ಬದಲಾದ ಪ್ರಕಾಶತೆಯ ರೇಖಾ ನಕ್ಷೆಯನ್ನು ಲೈಟ್ ಕರ್ವ್‌ಗಳೆನ್ನುವರು (ಚಿತ್ರ 5). ಇವು ಸ್ಟಾಂಡರ್ಡ್ ಕ್ಯಾಂಡಲ್‌ನಂತೆ ವರ್ತಿಸಿ ಖಗೋಳಕಾಯಗಳ ದೂರವನ್ನು ಕಂಡುಹಿಡಿಯಲು ಸಹಾಯವಾಗಿದೆ. ಇದರಿಂದ ನೋವಾ, ಸೂಪರ್ನೋವಾ, ವೇರಿಯಬಲ್ ನಕ್ಷತ್ರ ಮುಂತಾದವುಗಳನ್ನು ಅಧ್ಯಯನ ಮಾಡುವಾಗ ಪ್ರಕಾಶತೆಯಲ್ಲಾದ ಬದಲಾವಣೆಯನ್ನು ಅಧ್ಯಯನ ಮಾಡಬಹುದು. ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಸೂಪರ್ನೋವಾಗಳನ್ನು ವಿಂಗಡಣೆ ಮಾಡುವಾಗ ಅವುಗಳ 'ಲೈಟ್ ಕರ್ವ್'ಗಳ ಹೀರಿಕೊಳ್ಳುವ ಗೆರೆಗಳಲ್ಲಿ ($absorption\ lines$) ಜಲಜನಕದ ಬಾಲ್ಮರ್ ಗೆರೆಗಳ ಸರಣಿ ಇದ್ದಲ್ಲಿ ಟೈಪ್೨ ಸೂಪರ್ನೋವಾ ಆಗಿರುತ್ತವೆ, ಇಲ್ಲದಿದ್ದಲ್ಲಿ ಟೈಪ್೧ ಆಗಿರುತ್ತವೆ ಎಂದು ನಿರ್ಧರಿಸುತ್ತಾರೆ.



ಚಿತ್ರ 5 ಲೈಟ್ ಕರ್ವ್ಸ್

2....ಟೈಪ್2 ಸೂಪರ್ನೋವ

ಈ ಬಗೆಯ ಸೂಪರ್ನೋವಾಗಳು ಸುರುಳಿಯಾಕಾರದ ಗ್ಯಾಲಾಕ್ಸಿಗಳ ಬಾಹುಗಳಲ್ಲಿ ಕಂಡುಬರುತ್ತವೆ. ನಮ್ಮ ಸೂರ್ಯನಿಗಿಂತ ಕನಿಷ್ಠ 8 ಪಟ್ಟು ಅಥವಾ ಅದಕ್ಕಿಂತ ದೊಡ್ಡ ದೈತ್ಯನಕ್ಷತ್ರಗಳು ತಮ್ಮ ಅಂತಿಮ ಘಟ್ಟದಲ್ಲಿ ಶೀಘ್ರವಾಗಿ ಕುಸಿಯುವುದರಿಂದ ಟೈಪ್2 ಸೂಪರ್ನೋವಗಳು ಸಂಭವಿಸುತ್ತವೆ. ಇವುಗಳ ವರ್ಣಪಟಲದಲ್ಲಿ ಜಲಜನಕದ ಗೆರೆಗಳು ಕಾಣುವುದರಿಂದ ಟೈಪ್೨ ಸೂಪರ್ನೋವವನ್ನು ಬೇರೆಯದರಿಂದ ಪ್ರತ್ಯೇಕಿಸಬಹುದು. ಇವು ಸೂಪರ್ನೋವಾ ಆಗಿ ಸಿಡಿದು ಮಧ್ಯದಭಾಗವು ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರ ಅಥವಾ ಕಪ್ಪುಕುಳಿಯಾಗಿ ಹೊರಹೊಮ್ಮುತ್ತವೆ.

ಟೈಪ್2 ಸೂಪರ್ನೋವಗಳು ಸಂಭವಿಸುವ ಮುಂಚಿನ ತನಕ ಈ ದೈತ್ಯನಕ್ಷತ್ರಗಳು ತಮ್ಮಲ್ಲಿಯ ಶಾಖ ಮತ್ತು ಒತ್ತಡದಿಂದ ಪರಮಾಣು ಸಮ್ಮಿಳನ ಕ್ರಿಯೆ ನಡೆಯುತ್ತಿರುತ್ತದೆ. ಆಗ ತನ್ನಲ್ಲಿಯ ಜಲಜನಕವು ಹೀಲಿಯಂ ನಂತರದ ಪೀರಿಯಾಡಿಕ್

ಟೇಬಲ್‌ನಲ್ಲಿನ ಇತರ ಮೂಲವಸ್ತುಗಳ ಪರಮಾಣು ಸಮ್ಮಿಳನವಾಗಿ ಕಬ್ಬಿಣ, ನಿಕ್ಕಲ್ ತನಕ ಮುಂದುವರೆಯುತ್ತದೆ. ನಂತರ ಮುಂದೆ ಕಬ್ಬಿಣ ಮತ್ತು ನಿಕ್ಕಲ್‌ಗಿಂತ ಮುಂದಿನ ಭಾರವಾದ ಮೂಲವಸ್ತುಗಳು ಉತ್ಪತ್ತಿಯಾಗಲು ಹೆಚ್ಚು ಶಕ್ತಿ, ಉಷ್ಣತೆ ಬೇಕಿರುವುದರಿಂದ ತನ್ನ ಸಮ್ಮಿಳನ ಶಕ್ತಿಯನ್ನು ಕಳೆದುಕೊಂಡು, ಈ ದೈತ್ಯ ನಕ್ಷತ್ರವು ತನ್ನ ಕೇಂದ್ರದಲ್ಲಿ ಕಬ್ಬಿಣದ ಕೇಂದ್ರಭಾಗವನ್ನು ನಿರ್ಮಿಸುತ್ತದೆ. ಕಬ್ಬಿಣವು ಬೃಹತ್ ಪ್ರಮಾಣದಲ್ಲಿದ್ದಾಗ ಅಂತರಿಕ ಸಮ್ಮಿಳನ ಕ್ರಿಯೆಗಳ ಬಾಹ್ಯಸ್ಫೋಟಕ ಒತ್ತಡದ ಮೂಲಕ ತನ್ನನ್ನು ತಾನೇ ಬೆಂಬಲಿಸುವ ಸಾಮರ್ಥ್ಯವಾದ, ತನ್ನದೇ ಆದ ಗುರುತ್ವಾಕರ್ಷಣೆಯ ಪ್ರಚಂಡ ಏರಿಳಿತವನ್ನು ಎದುರಿಸಲು ವಿಫಲಗೊಳ್ಳುತ್ತದೆ. ಇದರಿಂದಾಗಿ ದೈತ್ಯನಕ್ಷತ್ರವು ಕುಸಿತಗೊಳ್ಳುತ್ತದೆ. ಈ ದೈತ್ಯವು ಸೂರ್ಯನ ದ್ರವ್ಯರಾಶಿಯ ೩ಕ್ಕಿಂತ ಕಡಿಮೆ ಇದ್ದಲ್ಲಿ ಕೇಂದ್ರದ ಕುಸಿತವು ಮುಂದುವರೆದು ಕಬ್ಬಿಣದ ನ್ಯೂಕ್ಲಿಯಸ್‌ಗಳು ಮತ್ತು ಸ್ವತಂತ್ರವಾಗಿದ್ದ ಎಲಕ್ಟ್ರಾನ್‌ಗಳು ಪುಡಿಪುಡಿಯಾಗಿ ನ್ಯೂಟ್ರಾನ್‌ಗಳಾಗಿ ರೂಪುಗೊಂಡು ಗಡುಸಾದ ಮುದ್ದೆಯಂತಾಗಿ ಮಧ್ಯಭಾಗದಲ್ಲಿ ಕೇಂದ್ರೀಕೃಗೊಂಡು ಗಿರಕಿ ಹೊಡೆಯಲು ಪ್ರಾರಂಭಿಸುತ್ತದೆ. ನಕ್ಷತ್ರಗಳ ಹೊರ ಪದರಗಳಲ್ಲಿರುವ ದ್ರವ್ಯವು ಇದರ ಮೇಲೆ ಬಿದ್ದಾಗ ಸೂಪರ್ನೋವಾ ಸಂಭವಿಸುತ್ತದೆ. ತಕ್ಷಣ ಹೊರಪದರವು ಗಡುಸು ಮೇಲ್ಮೆಯನ್ನು ಹೊಂದಿ ಅನಿಲವು ಶೇಖರಣೆಯಾಗುತ್ತದೆ. ನಂತರ ಅಗಾಧ ಒತ್ತಡಕ್ಕೊಳಗಾಗಿ ನ್ಯೂಟ್ರಾನ್‌ಗಳಿಂದ ತುಂಬಿದ ಕೇವಲ 20 ಕಿ.ಮೀ.ನಷ್ಟು ವ್ಯಾಸದಿಂದ ಕೂಡಿದ **ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರ**ವಾಗುತ್ತದೆ. ಅಗಾಧ ದ್ರವ್ಯರಾಶಿಯುಳ್ಳ ಇದರ ಒಂದು ಟೀ ಚಮಚ ದ್ರವ್ಯರಾಶಿಯು ಭೂಮಿಯ ಮೇಲೆ 50 ಶತಕೋಟಿ ಟನ್‌ಗಳಷ್ಟು ತೂಗುತ್ತದೆ. ದೈತ್ಯ ನಕ್ಷತ್ರವು ಸೂರ್ಯನ 3 ದ್ರವ್ಯರಾಶಿಗಿಂತ ಹೆಚ್ಚಾಗಿದ್ದಲ್ಲಿ ಇದರ ಕುಸಿತದಿಂದ ಹೆಚ್ಚು ಒತ್ತಡಕ್ಕೊಳಗಾಗಿ ಮತ್ತಷ್ಟು ಸಾಂದ್ರತೆಯಿಂದ ಕೂಡಿದ ಕಾಯವಾದ **ಕಪ್ಪು ಕುಳಿ** (*Black hole*) ಏರ್ಪಡುತ್ತದೆ. ಇದರ ಗುರುತ್ವಾಕರ್ಷಣ ಶಕ್ತಿಯು ಮತ್ತಷ್ಟು ಹೆಚ್ಚಾಗಿ ಇದ್ದು ಬೆಳಕೂ ಕೂಡ ಈ ಕಾಯದಿಂದ ತಪ್ಪಿಸಿಕೊಳ್ಳಲಾಗುವುದಿಲ್ಲ.

ಸೂಪರ್ನೋವಾ ವೀಕ್ಷಣೆಯ ಇತಿಹಾಸ

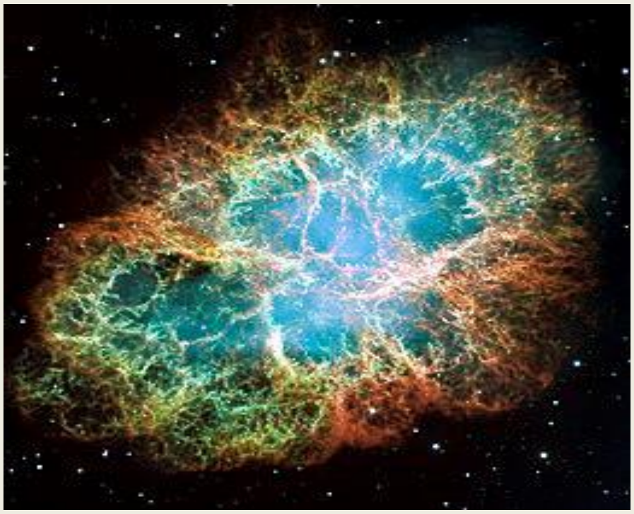
ನಮ್ಮ ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿರುವ ಸುಮಾರು 200 ಶತಕೋಟಿ ನಕ್ಷತ್ರಗಳಿದ್ದು, ಒಂದು ಶತಮಾನದಲ್ಲಿ (ಈ ಹಿಂದೆ ಘಟಿಸಿದ ಸೂಪರ್ನೋವ ವಿದ್ಯಮಾನದ ಆಧಾರದ ಮೇಲೆ) 2-3 ಸೂಪರ್ನೋವ ಸ್ಫೋಟವು ಕಾಣಿಸಿಕೊಳ್ಳಬಹುದು, ನಮ್ಮ ವೀಕ್ಷಣೆಯಿಂದ ಕೆಲವು ಸ್ಫೋಟಗಳು ಮರೆಯಾಗಿರಲೂ ಬಹುದು ಎಂದು ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಹೇಳುತ್ತಾರೆ.

ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ ಸಂಭವಿಸಿ ದಾಖಲಾಗಿರುವ ಕೆಲವು ಚರಿತ್ರಾರ್ಹ ಸೂಪರ್ನೋವಾಗಳೆಂದರೆ, *SN*185, *SN*1006, *SN*1054, *SN*1572, *SN*1947*A*, *SN*2017*JZP*.

ಸೆಂಟಾರಸ್ ನಕ್ಷತ್ರಪುಂಜದಲ್ಲಿ ಚೀನೀಯರು ಕ್ರಿ.ಶ. ೧೮೫ನಲ್ಲಿ ಬಹು ಪ್ರಕಾಶಮಾನವಾಗಿ ಆಗಸದಲ್ಲಿ 1-2 ವರ್ಷಗಳು ಸತತವಾಗಿ ಕಂಡು ಬಂದ ಹೊಸ ನಕ್ಷತ್ರ ಎಂದು ವಿವರವಾಗಿ ದಾಖಲಿಸಿದ್ದಾರೆ. ಈ *SN*185 ಮೊಟ್ಟಮೊದಲು ದಾಖಲಾದ ಅತ್ಯಂತ ಪುರಾತನವಾದ ಟೈಪ್1 ಸೂಪರ್ನೋವಾ ಆಗಿದೆ. ಇದು ಸ್ಫೋಟವಾದ 8 ತಿಂಗಳ ತನಕ ಚಲಿಸದೆ ಒಂದೇ ಸ್ಥಳದಲ್ಲಿ ಪ್ರಕಾಶಿಸುತ್ತಿದ್ದು ನಂತರ ಕಳೆಗುಂದಿತು ಎಂದು ಚೀನಾದ ಹ್ಯಾನ್ ರಾಜವಂಶದ ಕಾಲದ ಗ್ರಂಥಗಳಲ್ಲಿ ಲಿಖಿತವಾಗಿದೆ. ನಂತರ 393 *AD*ಯಲ್ಲಿ ಚೀನಾದೇಶದಲ್ಲಿ ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಅತಿಥಿ ನಕ್ಷತ್ರ ಎಂದು ದಾಖಲಿಸಿರುವ ಮತ್ತೊಂದು ಸೂಪರ್ನೋವಾ ಸಂಭವಿಸಿದೆ.

ಕ್ರಿ.ಶ.1006ರಲ್ಲಿ ನಕ್ಷತ್ರಗಳ ಇತಿಹಾಸದಲ್ಲೇ ಅತಿ ಪ್ರಕಾಶಮಾನವಾದ ಸೂಪರ್ನೋವ ಸ್ಫೋಟ ದಾಖಲಾಗಿದ್ದು, ಅದು ಚಿನ್ನದ ತಟ್ಟೆಯಂತೆ ರಾತ್ರಿಯ ಆಕಾಶದಲ್ಲಿ 3 ವರ್ಷಗಳ ಕಾಲ ಕಾಣುತ್ತಿತ್ತು ಎಂದು ಮತ್ತೊಂದು ದಾಖಲೆ ಹೇಳುತ್ತದೆ. ಇದೇ

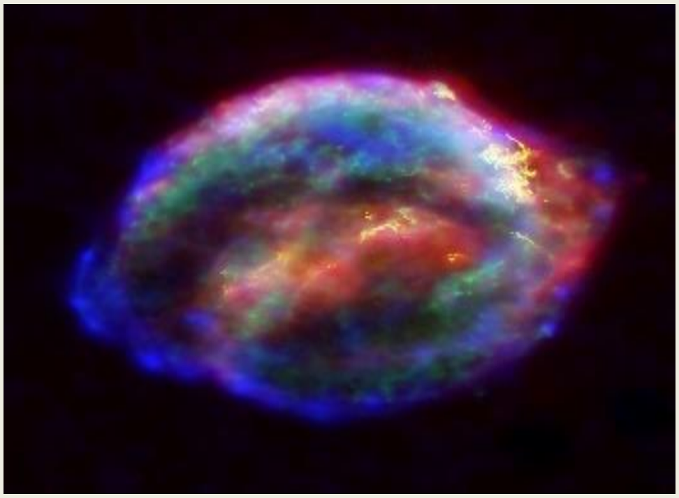
$SN1006$ ಸೂಪರ್ನೋವಾ. ಇದು ಲೂಪಸ್ ($Lupus$) ನಕ್ಷತ್ರಪುಂಜದಲ್ಲಿ ಭೂಮಿಗೆ 7100 ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿದ್ದು, ಅದರ ಅವಶೇಷವನ್ನು ಕಂಡುಹಿಡಿದಿದ್ದಾರೆ. ಇದಾದ 48 ವರ್ಷಗಳ ನಂತರ 1054 ADಯಲ್ಲಿ ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯ ಟಾರಸ್ ($Taurus$) ನಕ್ಷತ್ರಪುಂಜದಲ್ಲಿ ಸಂಭವಿಸಿದ್ದ $SN1054$ ಸೂಪರ್ನೋವಾಅನ್ನು ನ್ಯೂ ಮೆಕ್ಸಿಕೋದ ಸ್ಥಳೀಯರು ವೀಕ್ಷಿಸಿ ದಾಖಲು ಮಾಡಿದ್ದರು. ಇದು ಶುಕ್ರ ನಕ್ಷತ್ರದಂತೆ ಪ್ರಕಾಶಿಸುತ್ತಿದ್ದು, 23 ದಿನಗಳು ಹಗಲು–ರಾತ್ರಿಯಲ್ಲೂ ಕಾಣುತ್ತಿತ್ತು, ಅಲ್ಲದೆ 653 ದಿನಗಳು ರಾತ್ರಿಯಲ್ಲೂ ಪ್ರಕಾಶಿಸುತ್ತಿತ್ತು ಎಂದು ದಾಖಲಾಗಿದೆ. 1731ರಲ್ಲಿ ಫ್ರೆಂಚ್ ಖಗೋಳವಿಜ್ಞಾನಿಯಾದ ಜಾನ್ ಬೆವಿಸ್ ಈ ಸೂಪರ್ನೋವ ಸ್ಫೋಟದಿಂದಾದ ಇದರ ಅವಶೇಷವಾದ 'ಕ್ರಾಬ್ ನೆಬುಲ'ವನ್ನು ಕಂಡುಹಿಡಿದರು. ಈ ನೆಬುಲದಲ್ಲಿ ಸೂಪರ್ನೋವ ಸ್ಫೋಟದ ನಂತರ ಮಧ್ಯಭಾಗವು ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರವಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ. 2021ರ ಸಂಶೋಧನೆಯ ಪ್ರಕಾರ ಇದು 'ಎಲಕ್ಟ್ರಾನ್ ಕ್ಯಾಪ್ಚರ್ ಸೂಪರ್ನೋವಾ ಎಂದು ದೃಢಪಡಿಸಿದ್ದಾರೆ. ಇದರ ಅವಶೇಷವಾದ 'ಕ್ರಾಬ್ ನೆಬುಲ' (ಚಿತ್ರ 6) ವಿಸ್ತರಿಸುತ್ತಿದ್ದು ಸ್ಫೋಟಿಸಿದ 1000 ವರ್ಷಗಳಲ್ಲಿ 11 ಜ್ಯೋತಿರ್ವರ್ಷ ಅಗಲವಾಗಿ ವಿಸ್ತರಿಸಿದೆ ಎಂದು ತಿಳಿದುಬಂದಿದೆ.


ಚಿತ್ರ 6 ಕ್ರಾಬ್ ನೆಬುಲ

ಮತ್ತೊಂದು $SN1181$ ಸೂಪರ್ನೋವಾ 1181 ADಯಲ್ಲಿ ಕ್ಯಾಸಿಯೋಪಿಯಾ ($Cassiopeia$) ನಕ್ಷತ್ರಪುಂಜದಲ್ಲಿ ಸಂಭವಿಸಿತೆಂದು ಚೀನಾ, ಜಪಾನ್ ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ದಾಖಲಿಸಿದ್ದಾರೆ. ಇದರ ಅವಶೇಷವೇ ಆಗಿರಬಹುದೆಂದು $Pa30$ ಎಂಬ ನೆಬುಲಾವನ್ನು 2021ರಲ್ಲಿ ಕಂಡುಹಿಡಿಯಲಾಗಿದೆ. ಮುಂದೆ 1572ರಲ್ಲಿ ಅನೇಕ ವಿಜ್ಞಾನಿಗಳು ವೀಕ್ಷಿಸಿ ದಾಖಲು ಮಾಡಿರುವ ಖಗೋಳವಿಜ್ಞಾನಿಯ ಹೆಸರೇ ಇಟ್ಟಿರುವ ಟೈಕೊಬ್ರಾಹೆ ಸೂಪರ್ನೋವಾ ಕಾಣಿಸಿಕೊಂಡಿತು. ಇದು ಕ್ಯಾಸಿಯೋಪಿಯಾ ನಕ್ಷತ್ರಪುಂಜದಲ್ಲಿರುವುದರಿಂದ ಬಿ ಕ್ಯಾಸಿಯೋಪಿಯಾ ಸೂಪರ್ನೋವಾ ಎಂದೂ ಕರೆಯುವರು. ಇದು ಶುಕ್ರಗ್ರಹದಂತೆ ಹೊಳೆಯುತ್ತಿದ್ದು ಕ್ರಮೇಣ ಮುಸುಕಾಯಿತು. ಬ್ರಾಹೆ 1573ರಲ್ಲಿ ಇದರ ಬಗ್ಗೆ 'ಡಿ ನೋವಾ' ಎಂಬ ಪುಸ್ತಕವನ್ನು ಬರೆದು ಪ್ರಕಟಿಸಿದರು. 1960ರಲ್ಲಿ ಇದರ ಅವಶೇಷವನ್ನು ಕಂಡುಹಿಡಿಯಲಾಯಿತು.

1604ರಲ್ಲಿ ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ ಸಂಭವಿಸಿದ ಕಡೆಯ ಸೂಪರ್ನೋವಾ ಎಂದರೆ ಟೈಪ್1ಎ $SN1604$. ಇದನ್ನು ಅನೇಕ ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ವೀಕ್ಷಿಸಿದ್ದರಾದರೂ ಜೊಹಾನ್ಸ್ ಕೆಪ್ಲರ್ ($Johannes\ Kepler$) ಇದನ್ನು ವ್ಯವಸ್ಥಿತವಾಗಿ ಅಧ್ಯಯನ ಮಾಡಿ ಪುಸ್ತಕರೂಪದಲ್ಲಿ ಪ್ರಕಟಿಸಿದರು. ಇದನ್ನು ಕೆಪ್ಲರ್ ಸೂಪರ್ನೋವಾ ಎಂದೂ ಕರೆಯುವರು. ಇದು ಸ್ಫೋಟವಾದ ಒಂದು ವರ್ಷಗಳ ಕಾಲ ಬರಿಗಣ್ಣಿಗೇ ಕಾಣುತ್ತಿತ್ತು ಎಂಬ ಲಿಖಿತವಿದೆ. ಇದರ ಅವಶೇಷವನ್ನು 1941ರಲ್ಲಿ ಕಂಡುಹಿಡಿಯಲಾಯಿತು. ಚಂದ್ರ ಎಕ್ಸ್‌ರೇ ವೀಕ್ಷಣಾಲಯದಲ್ಲಿ ಇದರ ಬಹುತರಂಗಾಂತರ ಚಿತ್ರಣವನ್ನು ತೆಗೆಯಲಾಗಿದೆ (ಚಿತ್ರ 7). ಕೆಪ್ಲರನು ಕ್ರಿ.ಪೂ. ನಾಲ್ಕನೇ ಶತಮಾನದ ಶ್ರೇಷ್ಠ ತತ್ವಜ್ಞಾನಿಯಾದ ಅರಿಸ್ಟಾಟಲ್‌ನ 'ಬದಲಾಗದ ಸ್ವರ್ಗ' ಮತ್ತು 'ಭೂ ಕೇಂದ್ರ ಸಿದ್ಧಾಂತ' ಅಭಿಪ್ರಾಯಗಳನ್ನು ವಿರೋಧಿಸಿದ್ದನು. ಮೇಲಿನ ದಾಖಲೆಗಳೇ ಆಗ ಬೈಬಲ್‌ನಲ್ಲಿ ದಾಖಲಾಗಿದ್ದು, ಈ ಯಾವ ಸಿದ್ಧಾಂತಗಳಿಗೂ ಪ್ರತಿಯಾಗಿ ಮುಕ್ತ ಘೋಷಣೆ ಮಾಡುವಂತಿರಲಿಲ್ಲ. ನಂತರ ನಮ್ಮ ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ

ಯಾವ ಸೂಪರ್ನೋವಾ ಸ್ಫೋಟವೂ ಘಟಿಸಿಲ್ಲ. ಮುಂದಿನ ಸರದಿ ಬೀಟಲ್‌ಗೀಸ್, ರಿಗಲ್, ಸ್ಪೈಕ ಅಥವಾ ಈಟ ಕ್ಯರಿನ್‌ಗಳದಾಗಿದೆ.



ಚಿತ್ರ 7 ಚಂದ್ರ ಎಕ್ಸ್‌ರೇ ವೀಕ್ಷಣಾಲಯದ ಕೆಪ್ಲರ್ ಸೂಪರ್ನೋವಾದ ಅವಶೇಷ

ಸೂಪರ್ನೋವಾ ಸಂಭವಿಸುವುದನ್ನು ಕಂಡುಹಿಡಿಯುವಿಕೆ

1604ರ ನಂತರ ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ ಯಾವ ಸೂಪರ್ನೋವಾವೂ ಕಾಣಿಸಿಕೊಳ್ಳದಿದ್ದರೂ 1668-70ರಲ್ಲಿ ನಮ್ಮ ಸೂರ್ಯಮಂಡಲದಿಂದ ಆಚೆ ಕ್ಯಾಸಿಯೋಪಿಯಾ ನಕ್ಷತ್ರಪುಂಜದಲ್ಲಿ ಕಡಿಮೆ ಪ್ರಕಾಶಮಾನದ ಸೂಪರ್ನೋವಾ ಸ್ಫೋಟಗೊಂಡ ನಂತರ ಅದರ ಅವಶೇಷವಾಗಿ 'ಕ್ಯಾಸಿಯೋಪಿಯಾ ಎ' ಕಪ್ಪು ಕುಳಿ ರೂಪುಗೊಂಡು ಅದರ ರೇಡಿಯೋ ಮೂಲವಿರುವುದು ಕಂಡುಬಂದಿದೆ.

1931ರಲ್ಲಿ ವಾಲ್ಟರ್ ಬಾಡೆ ಮತ್ತು ಇತರ ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಮೌಂಟ್ ವಿಲ್ಸನ್ ವೀಕ್ಷಣಾಲಯದಲ್ಲಿ ವ್ಯವಸ್ಥಿತವಾಗಿ ಅಧ್ಯಯನ ಮಾಡಿ ನಕ್ಷತ್ರಗಳು ಗುರುತ್ವಾಕರ್ಷಣೆಯಿಂದ ಕುಸಿದು ಸೂಪರ್ನೋವಾ ಆಗಿ ಶಕ್ತಿಯನ್ನು ಬಿಡುಗಡೆ ಮಾಡುತ್ತವೆಯೆಂದು ಮತ್ತು ಕೇಂದ್ರದಲ್ಲಿ ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರಗಳಾಗುತ್ತವೆಯೆಂದು ಪ್ರತಿಪಾದಿಸಿದರು.

ಈಚೆಗೆ ಸೂಪರ್ನೋವಾ ಸಂಭವಿಸುವುದನ್ನು ಕಂಡುಹಿಡಿಯಲು ಕಂಪ್ಯೂಟರ್ ನಿಯಂತ್ರಿತ ದೂರದರ್ಶಕಗಳನ್ನು ಉಪಯೋಗಿಸುವರು. ಸೂಪರ್ನೋವಾ ಸಂಭವಿಸುವ ಮೊದಲು ಎಚ್ಚರಿಸುವಂತೆ ನ್ಯೂಟ್ರಿನೋಗಳು ಉತ್ಪತ್ತಿಯಾಗುತ್ತವೆ. ಆದ್ದರಿಂದ ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ನ್ಯೂಟ್ರಿನೋ ಪತ್ತೆಕಾರಕಗಳನ್ನು ಉಪಯೋಗಿಸುತ್ತಾರೆ. ಸೂಪರ್ನೋವಾ ಸಂಭವಿಸುವಾಗ ನಕ್ಷತ್ರಗಳ ಉಷ್ಣಾಂಶವು ಹೆಚ್ಚಾಗುವುದರಿಂದ ಕೆಂಪು ಬಣ್ಣದಿಂದ ನೀಲಿ ಬಣ್ಣಕ್ಕೆ ಬದಲಾಯಿಸಿ ನಮ್ಮ ಕಣ್ಣಿಗೆ ಕಾಣುತ್ತವೆ ಎಂದು ವರದಿ ಹೇಳುತ್ತದೆ.

ಬೇರೆ ಬೇರೆ ಗ್ಯಾಲಾಕ್ಸಿಗಳಲ್ಲಿ ಸಂಭವಿಸುವ ಸೂಪರ್ನೋವಾಗಳನ್ನು ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಮತ್ತು ಹವ್ಯಾಸಿ ಖಗೋಳವೀಕ್ಷಕರು ಸಂಶೋಧಿಸಿ ಅನೇಕ ಸೂಪರ್ನೋವಾಗಳ ಅಧ್ಯಯನ ಮಾಡಿದ್ದಾರೆ. ಅವುಗಳಲ್ಲಿ ಕೆಲವು ಕೆಳಗಿನಂತಿವೆ.

ಇತರ ಗ್ಯಾಲಾಕ್ಸಿಗಳಲ್ಲಿ ಸಂಭವಿಸಿದ ಸೂಪರ್ನೋವಾ

$SN1987A$

ಇದು ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯ ಸಮೀಪದ ಒಂದು ಕುಬ್ಜ ಸ್ಯಾಟಲೈಟ್ ಗ್ಯಾಲಾಕ್ಸಿಯ 'ದೊಡ್ಡ ಮ್ಯಾಗ್ನಲಿಕ್ ಕ್ಲೌಡ್'ನಲ್ಲಿ 1987ರಲ್ಲಿ ಘಟಿಸಿದ ಟೈಪ್2 ಸೂಪರ್ನೋವ. ಭೂಮಿಗೆ 1,68,000 ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿ ಆದ ಈ ಘಟನೆಯನ್ನು ಇತ್ತೀಚಿನ ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ವೀಕ್ಷಿಸಿ ಅಧ್ಯಯನ ಮಾಡಿದ ಮೊದಲ ಸೂಪರ್ನೋವ. ಸೂಪರ್ನೋವಾದ ಬೆಳಕು ಒಂದು ಗಂಟೆಯ ಕಾಲದೊಳಗೇ ಭೂಮಿಗೆ ತಲುಪಿತು. ಇದರಿಂದ ನ್ಯೂಟ್ರಿನೋ ಹೊರಸೂಸುವಿಕೆಯನ್ನು ಮೊದಲು ಪತ್ತೆಮಾಡಿದ್ದಾರೆ ಅಲ್ಲದೆ ವಿದ್ಯುತ್–ಕಾಂತ ವರ್ಣಪಟಲವನ್ನೂ ವೀಕ್ಷಿಸಲಾಗಿದೆ. ಇದರಿಂದ ಹೊರಸೂಸಲ್ಪಟ್ಟ ಗಾಮ ಮತ್ತು ಇತರ ರೇಡಿಯೊ ಆಕ್ಟೀವ್ ಕಿರಣಗಳನ್ನು ಅಧ್ಯಯನ ಮಾಡಿದ್ದಾರೆ. 2019ರಲ್ಲಿ ಇದರ ಅವಶೇಷದಲ್ಲಿ ಇದ್ದ ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರವು ಕುಸಿದಿರುವುದನ್ನು ದೂರದರ್ಶಕದಿಂದ ವೀಕ್ಷಿಸಲಾಗಿದೆ (ಚಿತ್ರ 8). 2024ರಲ್ಲಿ ಇದರಲ್ಲಿ ನಡೆಯುತ್ತಿರುವ ಅನೇಕ ನಿಗೂಢ ಪ್ರಕ್ರಿಯೆಗಳನ್ನು ಜೇಮ್ಸ್ ವೆಬ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕವು ಗುರುತಿಸಿದೆ.

ಈ ಸೂಪರ್ನೋವಾ ಘಟನೆಯನ್ನು ದಾಖಲಿಸಿದ 4 ದಿನಗಳ ನಂತರ ಇದರ ಮೂಲ ನಕ್ಷತ್ರವು ಸಂಡುಲೇಕ್–69202 ($Sanduleak - 69202$) ಎಂಬ ನೀಲಿದೈತ್ಯ ಎಂದು ತಿಳಿದುಬಂತು. ಈ ನಕ್ಷತ್ರದ ನೀಲಿ ಬಣ್ಣವು ಅದರೊಳಗಿನ ರಾಸಾಯನಿಕ ಸಂಯೋಜನೆಯಿಂದ ಎಂದು ಮತ್ತು ನ್ಯೂಟ್ರಿನೊ ಸಿಡಿತವೂ ಬೆಳಕಿನೊಡನೆ ಇರುವುದು ವೀಕ್ಷಣೆಯಿಂದ ತಿಳಿದುಬಂದಿದೆ. ನ್ಯೂಕ್ಲಿಯರ್ ಸಮ್ಮಿಳನದಿಂದ ಶಕ್ತಿಯನ್ನು ಉತ್ಪಾದಿಸಲಾಗದೆ ನಕ್ಷತ್ರವು ಕುಸಿತವನ್ನು ಕಂಡಿದೆ. ಈ ಕುಸಿತದ ವೇಗವು ಗಂಟೆಗೆ 7,50,000 ಕಿ.ಮೀ. ಇದ್ದು, ಉಷ್ಣಾಂಶವು ಹೆಚ್ಚುತ್ತಾ 100 ಶತಕೋಟಿ ಡಿಗ್ರಿಯ ವರೆಗೂ ತಲುಪಿರುವ ಮಾಹಿತಿ ದೊರಕಿದೆ. ಇದರಿಂದಾಗಿ ಎಲಕ್ಟ್ರಾನ್‌ಗಳು ಪ್ರೋಟಾನ್‌ನೊಡನೆ ಬಡಿದು ನ್ಯೂಟ್ರಾನ್‌ಗಳ ಸ್ಫೋಟಕ್ಕೆ ಕಾರಣವಾಗಿದೆ. ಈ ನ್ಯೂಟ್ರಾನ್‌ಗಳು ಬಲವಂತವಾಗಿ ಒಟ್ಟಾದ ಕಾರಣ ಭಾರವಾದ ಲೋಹಗಳಾದ ಕಬ್ಬಿಣ, ನಿಕ್ಕಲ್, ಚಿನ್ನ, ಯುರಾನಿಯಂ ಮುಂತಾದ ಮೂಲವಸ್ತುಗಳು ರೂಪಿವಾಗಿವೆ ಎಂದು ತಿಳಿದುಬಂದಿದೆ.

ಹಬಲ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕದಿಂದ ವೀಕ್ಷಿಸಲಾಗಿ ಈ ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರದ ಸುತ್ತ ಉಂಗುರಾಕಾರವಾಗಿ ಅನಿಲದಿಂದ ದಹಿಸುತ್ತಿರುವ ಒಂದು ಬೆಳಕಿನ ಉಂಗುರವನ್ನು ವೀಕ್ಷಿಸಿದ್ದಾರೆ. ಈ ಉಂಗುರಾಕಾರವು ಕಡೆಯ ಪಕ್ಷ 20,000 ವರ್ಷಗಳಿಂದಲೂ ದಹಿಸುತ್ತಿದ್ದು ಆ ನಕ್ಷತ್ರವು ಸ್ಫೋಟವಾಗುವ ಮುಂಚಿನಿಂದಲೂ ಇದೆಯೆಂದು ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಅಭಿಪ್ರಾಯಪಡುತ್ತಾರೆ. ನಕ್ಷತ್ರದ ಸ್ಫೋಟದಿಂದ ಉಂಟಾದ ನೇರಳಾತೀತ ಬೆಳಕು ಉಂಗುರದ ಅನಿಲವನ್ನು ಮತ್ತಷ್ಟು ಶಕ್ತಿಯುತವಾಗಿ ಮಾಡಿ ಹೆಚ್ಚಿನ ಪ್ರಕಾಶತೆಯನ್ನುಂಟುಮಾಡಿದೆ. ಇದಲ್ಲದೆ ಸುಮಾರು 19 ಸೂರ್ಯರಷ್ಟು ಉಷ್ಣತೆಯುಳ್ಳ ನಕ್ಷತ್ರಗಳ ದ್ರವ್ಯಗಳು ಮತ್ತು ರೇಡಿಯೋ ಆಕ್ಟೀವ್ ವಸ್ತುಗಳನ್ನು ಹೊರಚಾಚುತ್ತಿರುವುದನ್ನು ಹಬಲ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕವು ವೀಕ್ಷಿಸಿದೆ. ಜೇಮ್ಸ್

ಚಿತ್ರ 8 ಎಸ್ ಎನ್ 1987ಎ ಸೂಪರ್ನೋವಾದ ಅವಶೇಷದಲ್ಲಿ ಇರುವ ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರ

ವೆಬ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕದಿಂದ ಈ ಸೂಪರ್ನೋವಾ ಒಂದು ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರವಾಗಿ ಮಾರ್ಪಟ್ಟಿರುವುದನ್ನು ವೀಕ್ಷಿಸಲಾಗಿದೆ.

$SN2011dh$

ಚಿತ್ರ 9 ವಿರ್ಲ್‌ಪೂಲ್ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ ಸಂಭವಿಸಿದ $SN2011dh$ ಸೂಪರ್ನೋವ

2011ರಲ್ಲಿ ವಿರ್ಲ್‌ಪೂಲ್ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ $SN2011dh$ ಎಂಬ ಸೂಪರ್ನೋವ ಕಂಡುಹಿಡಿಯಲಾಯಿತು (ಚಿತ್ರ 9). ಹಳದಿ ದೈತ್ಯವು ಸೂಪರ್ನೋವ ಸಿಡಿದು, ಕೇಂದ್ರದಲ್ಲಿ ಪರಮಾಣು ಸಮ್ಮಿಳನದಲ್ಲಿ ಕೊನೆಗೊಂಡಿತು. ಇದನ್ನು ಹಬಲ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕವು ವೀಕ್ಷಿಸಿ ಚಿತ್ರಣವನ್ನು ಸೆರೆಹಿಡಿದಿದೆ. ಈ ವಿರ್ಲ್ ಪೂಲ್ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲೇ ಹಿಂದಿನ 17 ವರ್ಷಗಳಲ್ಲಿ ಇದು ಸಿಡಿದಿರುವ ಮೂರನೇ ಸೂಪರ್ನೋವ ಆಗಿದೆ. ಇದು ಬಹು ಅಪರೂಪದ ಘಟನೆ. ಏಕೆಂದರೆ ಸಾಮಾನ್ಯವಾಗಿ ನಮ್ಮ ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ 40 ವರ್ಷಗಳಿಗೆ ಒಂದು ಸೂಪರ್ನೋವ ಕಾಣಿಸಿಕೊಳ್ಳುತ್ತದೆ.

ಖಗೋಳ ವಿಜ್ಞಾನಿಗಳು ಇತ್ತೀಚೆಗಷ್ಟೆ ವೀಕ್ಷಿಸಿದಂತೆ ಭೂಮಿಗೆ ಸುಮಾರು 3000 ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿ 21 ಯುಗಳ ನಕ್ಷತ್ರಗಳ ವ್ಯವಸ್ಥೆಯಲ್ಲಿ ಸೂರ್ಯನಂತಹ 21 ನಕ್ಷತ್ರಗಳು, ಸೂಪರ್ನೋವ ಸಿಡಿತದಿಂದ ಆದ ತಮ್ಮ ಪಕ್ಕದ 21 ನ್ಯೂಟ್ರಾನ್ ನಕ್ಷತ್ರಗಳನ್ನು ಸುತ್ತುತ್ತಿರುವುದನ್ನು ಯೂರೋಪಿಯನ್ ಸ್ಪೇಸ್ ಏಜನ್ಸಿಯ ಗಿಯ ಮಿಷನ್ (($European\ space\ agrncy\ Gaia\ mission$) ವೀಕ್ಷಿಸಿದೆ. ಇದು ಸುತ್ತುತ್ತಿರುವ ಅವಧಿಯು 6 ತಿಂಗಳಿಂದ 3 ವರ್ಷಗಳವರೆಗೂ ವ್ಯತ್ಯಾಸವಾಗುತ್ತಿದೆ. ಇವುಗಳನ್ನು ಅನೇಕ ಭೂಮಿಯ ಮೇಲಿರುವ ದೂರದರ್ಶಕಗಳಾದ ಡಬ್ಲ್ಯು ಎಮ್ ಕೆಕ್ ವೀಕ್ಷಣಾಲಯ, ಹವಾಯ್‌ನ ಎಮ್ ಮೌನಕಿಯ, ಮತ್ತು ಚಿಲಿಯ ಲಾ ಸಿಲ್ಲಾ ವೀಕ್ಷಣಾಲಯವೂ ದೃಢಪಡಿಸಿದೆ.

ಉಲ್ಫ್ ರಯಟ್ ನಕ್ಷತ್ರ ($Wolf - Rayet\ Stars -\ WR\ stars$)

ಇವು ಕೆಲವು ದೈತ್ಯ ನಕ್ಷತ್ರಗಳು ತಮ್ಮ ಅಂತಿಮ ಘಟ್ಟದಲ್ಲಿ ಕೆಲಕಾಲ ತಾಳುವ ಹಂತವಾಗಿದೆ. ಹೊರ ಜಲಜನಕದ ಪದರವನ್ನು ಪೂರ್ತಿಯಾಗಿ ಕಳೆದುಕೊಂಡು, ತಮ್ಮ ಕೇಂದ್ರದಲ್ಲಿ ಹೀಲಿಯಂ ಅಥವಾ ಭಾರವಾದ ವಸ್ತುಗಳನ್ನೊಳಗೊಂಡಿರುತ್ತವೆ. ಇಂತಹ ನಕ್ಷತ್ರಗಳು ಭೂಮಿಯಿಂದ ಸುಮಾರು 15000 ಜ್ಯೋತಿರ್ವರ್ಷ ದೂರದಲ್ಲಿ ಸಗಿಟೇರಿಯಸ್ ನಕ್ಷತ್ರಪುಂಜದಲ್ಲಿವೆ. ಇವು ಸೂಪರ್ನೋವಾ ಆಗಿ ಸಿಡಿಯುವ ಮುಂಚಿತವಾಗಿ ಈ ಉಲ್ಫ್ ರಯಟ್ ಹಂತವನ್ನು ಪಡೆದಿರುತ್ತವೆ (ಚಿತ್ರ 10).

ಚಿತ್ರ 10 ಸಗಿಟೇರಿಯಸ್ ನಕ್ಷತ್ರಪುಂಜದಲ್ಲಿ ಉಲ್ಫ್ ರಯಟ್ ನಕ್ಷತ್ರಗಳು

ಇವುಗಳ ಮೇಲ್ಮೈ ಉಷ್ಣಾಂಶವು 20,000ದಿಂದ 2,10,000 ಕೆಲ್ವಿನ್‌ವರೆಗೂ ಇದ್ದು ಆಗಸದಲ್ಲಿ ಅತಿ ಪ್ರಕಾಶಮಾನವಾಗಿ ಹೊಳೆಯುತ್ತವೆಯಾದರೂ, ನೇರಳಾತೀತ ಕಿರಣಗಳನ್ನು ಹೆಚ್ಚು

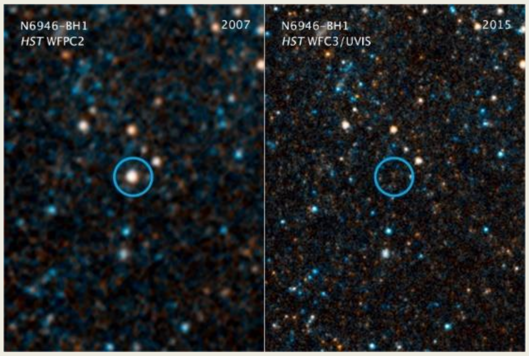
ಹೊರಹಾಕುತ್ತವೆ. ಇವುಗಳನ್ನು ಮೊದಲು ಗುರುತಿಸಿದವರು 1867ರಲ್ಲಿ ಪ್ಯಾರಿಸ್ ವೀಕ್ಷಣಾಲಯದಲ್ಲಿನ ಫೋಕಾಲ್ಟ್ ದೂರದರ್ಶಕದಲ್ಲಿ ಚಾರ್ಲ್ಸ್ ಉಲ್ಫ್ ಮತ್ತು ಜಾರ್ಜ್ ರಾಯಟ್ ಎಂಬ ಖಗೋಳ ವಿಜ್ಞಾನಿಗಳು. 30ಡೊರಡುಸ್‌ನಲ್ಲಿರುವ $R136a1$ ನಕ್ಷತ್ರವೂ ಉಲ್ಫ್ ರಯಟ್ ನಕ್ಷತ್ರವೇ.

ಅತ್ಯಂತ ಪುರಾತನವಾದ ಸೂಪರ್ನೋವಾ ಎಂದರೆ 11.5 ಶತಕೋಟಿ ವರ್ಷಗಳ ಹಿಂದೆ ಒಂದು ಕೆಂಪು ದೈತ್ಯ ನಕ್ಷತ್ರವು ಸಿಡಿದು ಸೂಪರ್ನೋವಾ ಸಂಭವಿಸಿದ್ದು ಅದನ್ನು ಹಬಲ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕವು 2022ರಲ್ಲಿ ಗುರುತಿಸಿದೆ. ಇದು ಅಬೆಲ್–370 ಎಂಬ ಗ್ಯಾಲಾಕ್ಸಿಯ ಹಿಂಭಾಗದಲ್ಲಿದ್ದು ಅದು ಅನೇಕ ಕಾರಣಗಳಿಗೆ ಪ್ರಾಮುಖ್ಯತೆ ಪಡೆದಿದೆ. ಆ ವೇಳೆಯಲ್ಲಿ ನಕ್ಷತ್ರಗಳಿಂದ ಕೂಡಿದ ಗ್ಯಾಲಾಕ್ಸಿಗಳು ಒಂದಕ್ಕೊಂದು ಹತ್ತಿರದಲ್ಲಿದ್ದ ಕಾರಣ ವಿಶ್ವದಲ್ಲಿ ಗುರುತ್ವಾಕರ್ಷಣೆಯು ಹೆಚ್ಚಾಗಿದ್ದು ವಿಸ್ತರಿಸುವಿಕೆಯು ನಿಧಾನಗತಿಯಲ್ಲಿತ್ತು. ನಂತರದಲ್ಲಿ ಕಪ್ಪು ಶಕ್ತಿಯು ಮೇಲುಗೈಯಾಗಿ ವಿಶ್ವದ ವಿಸ್ತರಿಸುವಿಕೆಯು ವೇಗೋತ್ಕರ್ಷವನ್ನು ಪಡೆಯುತ್ತಿದೆ.

ವಿಶ್ವದಲ್ಲಿ ಸಂಭವಿಸಿದ ಅತ್ಯಂತ ದೊಡ್ಡ ಸೂಪರ್ನೋವಾ ಎಂದರೆ 2020ರಲ್ಲಿ ಕಂಡುಹಿಡಿದ $AT2021LWX$ ಎಂಬುದು. ಇದು ಸೂರ್ಯನಿಗಿಂತ 2×10^{12}ಪಟ್ಟು ಪ್ರಕಾಶಮಾನವಿದ್ದು, ಸೂರ್ಯನಿಂದ ೧೦ ಶತಕೋಟಿ ವರ್ಷಗಳಲ್ಲಿ ಹೊರಸೂಸುವ ಶಕ್ತಿಯನ್ನು ಬಿಡುಗಡೆ ಮಾಡಿದೆ.

ವಿಫಲವಾದ ಸೂಪರ್ನೋವಾ

ಕೆಲವು ದೈತ್ಯ ನಕ್ಷತ್ರಗಳು ತಮ್ಮ ಅಂತಿಮ ಘಟ್ಟದಲ್ಲಿ ತಮ್ಮ ಕೇಂದ್ರದಲ್ಲಿ ಕುಸಿತವನ್ನು ಕಂಡರೂ ಅದು ಗೋಚರವಾಗುವುದಿಲ್ಲ ಮತ್ತು ಪತ್ತೆ ಮಾಡಲಾಗುವುದಿಲ್ಲ. ಅದರ ಕೇಂದ್ರವು ಅಧಿಕ ಪ್ರಮಾಣದಲ್ಲಿ ದ್ರವ್ಯರಾಶಿಯನ್ನೊಳಗೊಂಡಿರುತ್ತದೆ. ಕೆಲವು ಸಮೀಕ್ಷೆಗಳಿಂದ ಗುರುತಿಸಿರುವ ಇಂತಹ ಘಟನೆಗಳೆಂದರೆ $NGC4946$ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿರುವ, $N6946BH1$ ಎಂಬ ಕೆಂಪು ದೈತ್ಯವು 2007ನೇ ರಲ್ಲಿ ಕಂಡು ಯಾವ ಸ್ಫೋಟವೂ ಇಲ್ಲದೆ 2015ರಲ್ಲಿ ಕಣ್ಮರೆಯಾಯಿತು. ಇದು ಮುಸುಕಾಗುವ ವೇಳೆಗೆ ಅದರ ಸ್ಥಳದಲ್ಲಿ ಮಂದವಾದ ಅವಗೆಂಪು ಬಣ್ಣವನ್ನು ತಾಳುತ್ತಿದೆ (ಚಿತ್ರ 11). ಭೂಮಿಯಿಂದ 22 ದಶಲಕ್ಷ ಜ್ಯೋತಿರ್ವರ್ಷಗಳ ದೂರದಲ್ಲಿ ಇರುವ ಇದು ಸೂರ್ಯನ 25ರಷ್ಟು ದ್ರವ್ಯರಾಶಿಯನ್ನು ಹೊಂದಿದ್ದು ಸ್ಫೋಟಕ್ಕೆ ಮುಂಚಿತವಾಗಿ ಸೂರ್ಯನ 1,00,000 ರಷ್ಟು ಪ್ರಕಾಶವಾಗಿತ್ತೆಂದು ತಿಳಿದುಬಂದಿದೆ. ಸ್ಫೋಟದ ನಂತರ ಇದು ಹೊರಸೂಸುತ್ತಿರುವ ಅವಗೆಂಪು ಕಿರಣವು ಸೂರ್ಯನು ಹೊರಸೂಸುವ 5000ರಷ್ಟು ಇದೆ.



ಚಿತ್ರ 11 ವಿಫಲವಾದ ಸೂಪರ್ನೋವಾ (ಎಡಭಾಗ) ಕೆಂಪು ದೈತ್ಯ ನಕ್ಷತ್ರದ ಮಧ್ಯಭಾಗವು ಕಪ್ಪುರಂಧ್ರವಾಗಿರುವುದು(ಬಲಭಾಗ)

ಖಗೋಳ ವಿಜ್ಞಾನಿಗಳ ಪ್ರಕಾರ ಈ ವಿಫಲವಾದ ಸೂಪರ್ನೋವಾದ ಕೆಂಪು ದೈತ್ಯ ನಕ್ಷತ್ರದ ಮಧ್ಯಭಾಗವು ಕಪ್ಪುರಂಧ್ರವಾಗಿ ಕುಸಿದು, ದ್ರವ್ಯವು ನ್ಯೂಟ್ರಿನೊ ಆಗಿ ಸಿಡಿದುಹೋಗಿದೆ. ಸಾಮಾನ್ಯವಾಗಿ ಸೂಪರ್ನೋವಾ ಆಗಿ ಸಿಡಿದ ನಂತರ

ಕಪ್ಪುರಂಧ್ರವಾಗುತ್ತದೆ, ಆದರೆ ಇಲ್ಲಿ ಸೂಪರ್ನೋವಾ ಸಂಭವಿಸದೆ ಬದಲಿ ಮಾರ್ಗವನ್ನು ಅನುಸರಿಸಿದೆಯೆಂದು ವಿಜ್ಞಾನಿಗಳ ನಂಬಿಕೆ. ಇಲ್ಲಿ ನಕ್ಷತ್ರವು ಕಪ್ಪುರಂಧ್ರವೇ ಆಗಿದ್ದಲ್ಲಿ ಇದೇ ಮೊದಲನೇ ಬಾರಿ ಕಪ್ಪುರಂಧ್ರವು ರೂಪುಗೊಂಡಿರುವುದನ್ನು ವೀಕ್ಷಿಸಲಾಗಿದೆ ಎಂದು ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಹೇಳುತ್ತಾರೆ. ಇದನ್ನು ಹಬಲ್ ಮತ್ತು ಸ್ಪಿಡ್ಸರ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕದಲ್ಲಿ ವೀಕ್ಷಿಸಲಾಗಿದೆ.

ಜೇಮ್ಸ್ ವೆಬ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕವು ವೀಕ್ಷಿಸಿದ ಆಧಾರದಂತೆ ಎರಡು ನಕ್ಷತ್ರಗಳು ವಿಲೀನಗೊಂಡು ಸೂಪರ್ನೋವಾ ಆಗಲು ವಿಫಲಗೊಂಡಿದೆಯೆಂದು ತಿಳಿದುಬಂದಿದೆ.

ಸೂಪರ್ನೋವಾ ಸರ್ಚ್ ಪ್ರೋಗ್ರಾಮ್‌ನಿಂದ ಸುಮಾರು 16,000ಕ್ಕೂ ಹೆಚ್ಚು ಸೂಪರ್ನೋವಾಗಳನ್ನು ಕಂಡುಹಿಡಿಯಲಾಗಿದೆ. ಮುಂದಿನ 10-12 ವರ್ಷಗಳಲ್ಲಿ ಅಂತರ ತಾರಾವಲಯದಲ್ಲಿ ಸಂಭವಿಸುವ ಲಕ್ಷಾಂತರ ಸೂಪರ್ನೋವಾಗಳನ್ನು ಕಂಡುಹಿಡಿಯುವ ಯೋಜನೆ ಇದೆ. ಕ್ಷೀರಪಥ ಗ್ಯಾಲಾಕ್ಸಿಯಲ್ಲಿ ಸುಮಾರು 1,000 ಸೂಪರ್ನೋವಾ ಅವಶೇಷಗಳಿವೆಯೆಂದು ಲೆಕ್ಕ ಹಾಕಿದ್ದಾರೆ. ಇವುಗಳಲ್ಲಿ 300ಕ್ಕೂ ಹೆಚ್ಚು ಸೂಪರ್ನೋವಾಗಳನ್ನು ಕಂಡುಹಿಡಿದಿದ್ದಾರೆ.

ಸಂಗ್ರಹ: ಅಂತರ್ಜಾಲ

The Accidental Discovery That Changed Breakfast Forever

In 1895, a scientist named Percy Spencer was working with a radar magnetron—a device that emits microwaves—when he noticed something peculiar. The chocolate bar in his pocket had melted! Intrigued, he conducted further experiments, placing popcorn kernels near the device. To his amazement, they started popping.

Spencer realized that microwaves could heat food quickly and efficiently. This accidental discovery led to the invention of the **microwave oven**, a kitchen staple that revolutionized cooking worldwide.

Science often progresses through unexpected moments like this, proving that curiosity and observation can lead to groundbreaking innovations—even in the middle of a workday snack mishap!

Academic activities of H D Ananda

1. 7th Nov 2024 - Talk at B.E.T Convent, Bengaluru
2. 11th Nov 2024 - Talk at BMS College of Engineering, Bengaluru
3. 12th Nov 2024 - Chief Guest & Address at Vijaya College, Bengaluru
4. 17th Nov 2024 - Webinar by Karnataka Physics Association (KPA)
5. 27th Nov 2024 - Talk at RNSIT, Bengaluru
6. 3rd Dec 2024 - Talk at RNSIT, Bengaluru
7. 10th Dec 2024 - Address at RNS Pre-University College, Bengaluru
8. 13th Dec 2024 - Session for Student Induction at MES College, Bengaluru
9. 18th Dec 2024 - Chief Guest & Address at Smt. Parvathamma Shivashankarappa PU College, Davanagere
10. 18th Dec 2024 - Address at Bapuji Institute of Engineering & Technology, Davanagere
11. 19th Dec 2024 - Session at Bapuji Institute of Engineering & Technology, Davanagere
12. 21st Dec 2024 - Chief Guest at Annual Day, Mount Carmel English School, Bengaluru
13. 4th Jan 2024 - Webinar by Creative, Gauribidanur
14. 11th Jan 2024 - Talk at Global Academy, Bengaluru

Selected activities of Dr. B. A. Kagali

1. 9th Nov 2024 - Talk on ‘The life and legacy of C. V. Raman,’ Govt. High School, Thanisandra, Bengaluru
2. 12th Nov 2024 - Interaction with students, BBMP PU College, Magadi Road, Bengaluru
3. 13th Nov 2024 - Demonstration of experiments in physics, Govt. High School, Shivajinagar, Bengaluru
4. 27th Nov 2024 - Physics experimental demonstration, BBMP High School, Kamakshipalya, Bengaluru
5. 29th Nov 2024 - Demonstration of experiments in physics, BBMP High School, Magadi Road, Bengaluru
6. 6th Dec 2024 - Delivered two talks (‘Variational principles’ and ‘White dwarfs’) at a workshop for teachers and research students, University of Mysore
7. 28th Dec 2024 - Demonstration of low-cost experiments, Gavi Siddeshwara PU College, Koppal
8. 29th Dec 2024 - Talk on ‘Artificial intelligence’ for physics teachers, Sri Chaitanya College, Ballari

Innovative but simple low-cost experiments demonstrated in physics and chemistry for high school/PU students by Dr. Basavaraj Kagali, Sri Liyakhat Ali Khan, and Sri J. Basavaraju at the following schools

1. 13th Nov 2024 - VKO Govt. High School, Shivajinagar
2. 25th Nov 2024 - BBMP High School, Kodandaramapura
3. 28th Nov 2024 - BBMP Girls PU College, Shrirampura
4. 9th Dec 2024 - BBMP High School, Magadi Road
5. 30th Dec 2024 - BBMP High School, Venkateshpura
6. 2nd Jan 2025 - BBMP High School, Byadarahalli

Activities of Dr.B S Srikanta

1. 9th Nov 2024 - Govt. High School, Thanisandra - Lecture cum demonstration class on Ohm's Law
2. 12th Nov 2024 - Government First Grade College, Gauribidanur - Lecture on "C.V. Raman - Life and His Works"
3. 22nd Nov 2024 - Vivekananda High School, Sulibele, Hoskote Taluk - Demonstration class on Electricity for 10th standard students
4. 3rd Dec 2024 - Aditya Institute of Management Studies - Lecture on "Sustainability - Paradigm Shift in Global Business Practices"
5. 12th Dec 2024 - Oxford Engineering College, Bengaluru - Lecture on "Education - A Key for Empowering Future"
6. 11th Jan 2025 - NSS Bhavan, Bangalore University - Lecture on "Importance of NSS in Educational Institutions" during the camp for programme officers of BU colleges

Experimental workshops

Rajeshwari School, RR Nagar

Kaveripura High school, Bengaluru

Srividya High school, Nelamangala

Kamakshipalya High school, Bengaluru

Shivajinagar Govt. High School

Workshop on AI at Ballari Sri Chaitanya College

Invited talks by H D Ananda

Smt. Parvathamma Shivashankarappa PU College, Davanagere

Science Exhibition Holalkere

Ambedkar Institute of Technology, Bengaluru

Workshop at BIT, Bengaluru

Talks by Dr. B.S. Srikanta

Thanisnadra high school

Sulibele high school

Oxford Eng. College, Bengaluru

Gauribidanur College on C V Raman

Talk at Kuppam

Talk at Ballari High school

Workshop at Mandya

Talk at Kalaburgi

REPORT ON THE WORKSHOP ON THE ROLE OF ARTIFICIAL INTELLIGENCE IN PHYSICS TEACHING AND LEARNING

The said workshop was held on 29th of December, 2024 at Ballari in collaboration with Sri Chaitanya Group of Institutions for PU Physics teachers of Ballari district. It was inaugurated by Dr.M P Ravindra, Founder Vice Chancellor of Manipal University, Malaysia. Dr.P Radhakrishna, Chairman of the Chaitanya Group of Institutions presided over the inaugural function and kindly made all arrangements for the workshop. Sri. Veerabhadrappa, President, Physics Forum of Ballari and others participated in the Inauguration. Talks on various aspects of AI and its role in physics teaching, with practical demonstrations, were presented by Dr.B A Kagali, Dr.M P Ravindra, Dr.M S Jogad (Kalaburagi) and Dr. Ramakrishna (president, IAPT, Hyderabad). About fifty teachers from all over Ballari district participated in the event. Dr.S Somasekhara (KPA Joint Secretary) served as the coordinator of the workshop. The participants expressed their happiness for being introduced to the emerging field of Artificial Intelligence in the feedback session.

REPORT ON WORKSHOP ON ‘PHYSICS FOR ENGINEERS

A one day workshop on “Physics for Engineers” was arranged on 3rd January 2025. It was hosted by BIT, Bengaluru. The program was organized by the Dept. of Physics of BIT in association with KPA. There were two talks arranged in the morning session after the inauguration of the program which was presided over by the Principal of BIT. In the afternoon session, a ‘Physics model making’ contest was held for the students. Prof. N Udaya Shankar from Raman Research Institute delivered a talk on ‘Engineering challenges in Radio Astronomy’. This was followed by a talk on ‘Nanomaterials and their Applications’ by Dr. Basavaraj Angadi, from Bangalore University. Dr. Basavaraj Kagali & Dr. Nagaraju P served as judges for the physics model making contest in the afternoon and distributed the prizes.” Dr.S P Basavaraju served as the coordinator of the workshop. Around 150 students participated in the event.

Sl. no.	Date	Speaker	topic
1	03.11.24	Prof.V A Raghnathan	Physics of soft matter
2	10.11.24	Prof.B Rudraswamy	Nuclear Reactors
3	17.11.24	Sri.H D Ananda	All about MCF at Hassan
4	24.11.24	Ms.Akshatha Vydula	Cosmic dawn with 21 cm signal
5	01.12.24	Prof. N Karunakara	Fascinating applications of Carbon determination
6	15.12.24	Dr.C S Shivananda	Superconductivity and its applications quantum computing
7	22.12.24	Prof.R Shankar	The story of oceans
8	05.01.25	Prof.K Siddappa	Interdisciplinary research with Microtro
9	12.01.25	Prof.H S Mani	Fun problems in Physics