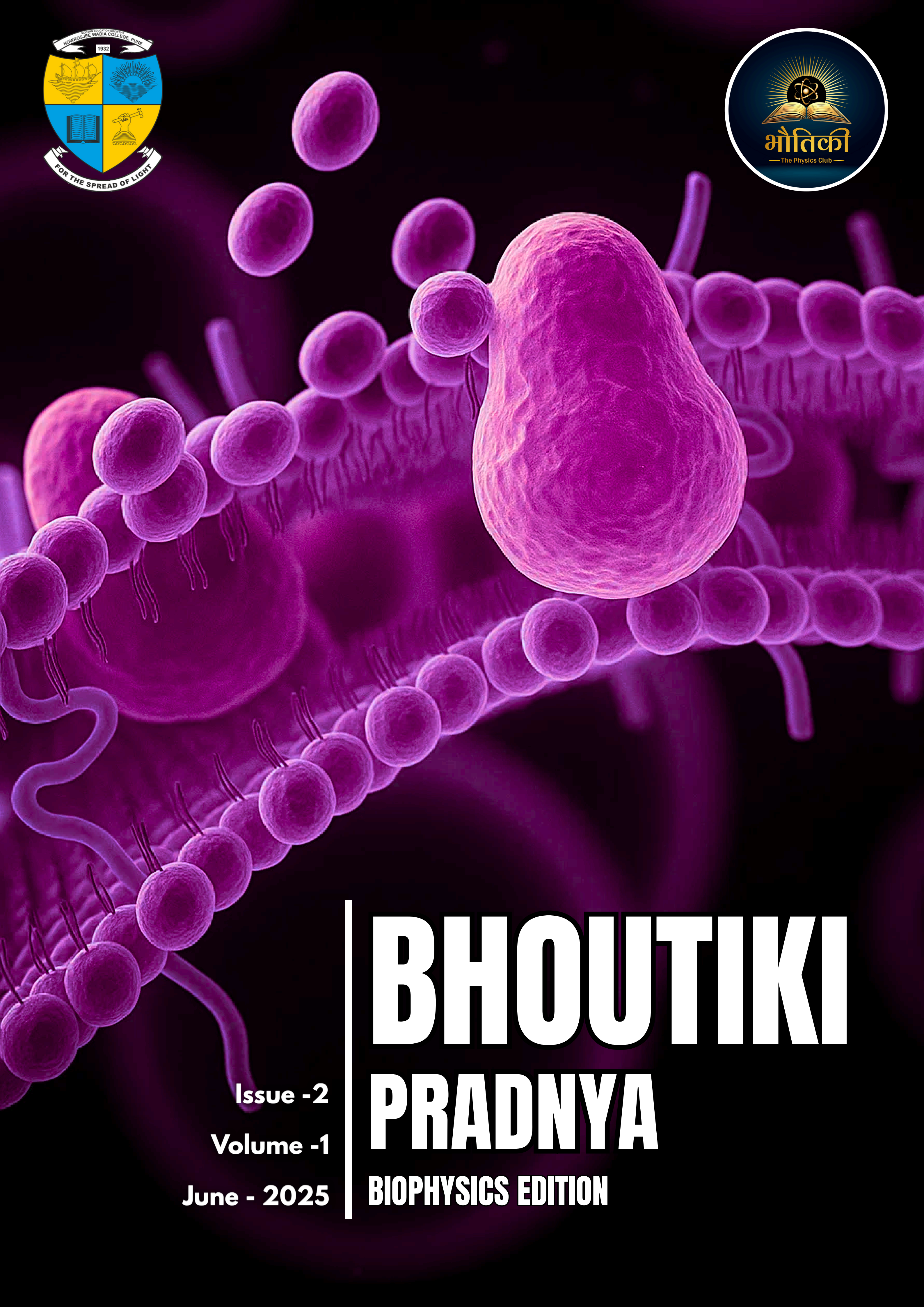

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BHOUTIKI PRADNYA

BIOPHYSICS EDITION

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CONTENTS

Biophysics at the Crossroads: Advancing Health, Space, and Nanotechnology

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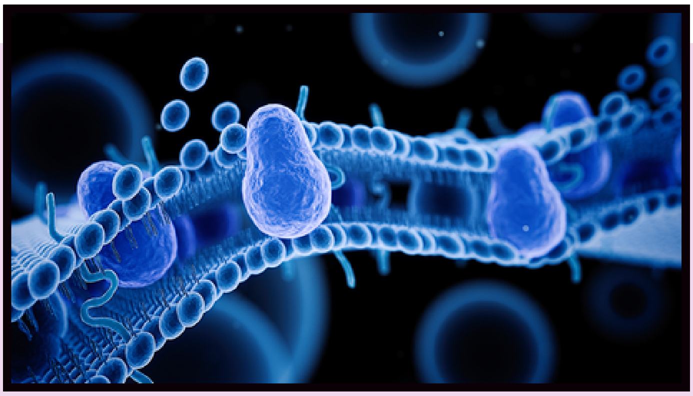
"It is impossible to make progress in understanding biology without using the concepts and techniques of physics."
- Francis Crick

This timeless statement by Francis Crick highlights the foundational role of physics in modern biology. Biophysics, as a discipline, brings together tools, theories, and concepts from physics to unravel the complexity of living systems—from the behavior of molecules to the physiology of entire organisms. In today's world, where interdisciplinary innovation drives technological progress, biophysics has emerged as a central force in health sciences, space research, and nanotechnology.



1. Biophysics: A Convergence of Disciplines

Biophysics occupies a unique space in science, bridging biology with the mathematical precision of physics. It plays a critical role in decoding the mechanisms that sustain life, whether in diagnosing diseases, designing biomaterials, developing radiotherapy strategies, or simulating life in space environments.

Biophysics spans a wide range of subfields, including:

- **Neurobiophysics**
- **Cellular and Molecular Biophysics**
- **Radiotherapy and Medical Biophysics**
- **Nanobiotechnology**
- **Astrobiology**
- **Gravitational Biology**

Each of these domains brings a unique perspective and set of applications that are transforming both basic science and real-world solutions.

2. Neurobiophysics: Understanding the Brain through Physics

Neurobiophysics explores how the brain processes information, communicates via electrical impulses, and adapts through neural plasticity. Researchers study ion channel dynamics, synaptic behavior, and signal transmission using physical and mathematical models.

Recent advances include:

- **Connectomics:** Mapping neural circuits with unprecedented resolution.
- **Neurophotonics:** Using light to study and manipulate brain activity.
- **BCIs and Neuroprosthetics:** Translating neural signals into device control for paralyzed individuals.
- **AI-based Brain Modeling:** Using spiking neural networks and biologically inspired architectures to simulate human cognition and behavior.

This field is instrumental in developing treatments for neurological diseases like Parkinson's and Alzheimer's by identifying early biophysical markers at the cellular level.

3. Cellular and Molecular Biophysics: Mechanisms at the Nanoscale

Cells have been shown to actively sense and respond to the mechanical and structural properties of their surrounding environment. Deciphering the mechanisms behind this mechano-sensation is essential to understanding how cells detect and interpret physical cues, and how these cues influence intracellular signaling, developmental pathways, and critical processes such as embryogenesis. This knowledge is particularly important for unraveling the cellular responses involved in pathological conditions and injury scenarios, such as trauma to the brain, spinal cord, or peripheral nerves. Insights gained could pave the way for advanced regenerative strategies and therapeutic interventions. Advanced biophysical tools have played a vital role in these investigations. Atomic Force Microscopy (AFM) has become a cornerstone technique, offering high-resolution, real-time morphological and mechanical mapping of living cells. Similarly, Optical Tweezers, capable of measuring forces in the piconewton (pN) range have become invaluable for probing the mechanobiological properties of cells and biomolecules with exceptional precision.

Molecular biophysics investigates the structural and functional properties of biomolecules such as proteins, DNA, and cell membranes. Using high-precision tools like **cryo-EM**, **NMR spectroscopy**, and **molecular dynamics simulations**, scientists decode how molecules fold, interact, and perform essential functions.

Notable breakthroughs:

- **AlphaFold by DeepMind** has accurately predicted protein structures, solving a decades-long problem in biology.
- **Real-time Single-Molecule Imaging** now enables observation of molecular events in living cells.
- **Quantum and Classical Simulations** are used in drug design and enzymatic activity modeling.

These insights are directly contributing to personalized medicine, vaccine development, and synthetic biology.

4. Radiotherapy and Medical Biophysics: Precision in Treatment

Radiotherapy is among the most successful applications of biophysics in healthcare. By understanding how ionizing radiation interacts with biological tissues, biophysicists ensure safer and more effective cancer treatments.

Modern techniques include:

- **IMRT** and **IGRT** for targeted treatment with minimal side effects.
- **Proton and Heavy Ion Therapy** for precision targeting of tumors.
- **Radiobiology Research** to optimize dose responses and repair mechanisms.

International collaboration, supported by agencies like the **IAEA**, is vital to developing next-generation treatment protocols.

5. Nanobiotechnology: Engineering at the Interface of Physics and Life

Nanobiotechnology merges nanoscience with biology, enabling manipulation of systems at the molecular level. It plays a transformative role in diagnostics, therapeutics, and regenerative medicine.

Key applications:

- **Targeted Drug Delivery** using nanoparticles and liposomes.
- **Nanosensors** for ultra-sensitive detection of biomarkers.
- **Quantum Dots and Imaging Tools** for tracking cellular events.
- **Tissue Engineering** using biocompatible scaffolds.

Research in this field is driven by collaboration between universities, biotech startups, and pharmaceutical giants.

6. Astrobiology: Searching for Life beyond Earth
Astrobiology is the study of life's origin, evolution, and existence in the universe. It is inherently interdisciplinary, combining geology, microbiology, planetary science, and astrophysics.

Recent global milestones:

- **NASA's OSIRIS-REx** mission returned asteroidsamples containing amino acids and nucleobases.
- **James Webb Space Telescope (JWST)** detected potential biosignatures in the atmosphere of exoplanet K2-18b.
- **ESA's JUICE mission** is exploring icy moons for habitability.
- **NASA's Dragonfly (2028)** will probe Titan's prebiotic chemistry.

These discoveries bring humanity closer to understanding whether life exists elsewhere in the cosmos.

7. Gravitational Biology: India's Strategic Frontier
Gravitational biology studies how changes in gravitational forces like microgravity or low gravity in space or hypergravity in simulations impact living organisms. This field is essential for sustaining life in long-term space missions and designing bioregenerative systems.

India has taken significant strides, particularly under ISRO's **Gaganyaan** mission.

🔬 ***Plant Research: Prof. P.B. Vidyasagar, SPPU***

Prof. Vidyasagar and his team at **Savitribai Phule Pune University** have led pioneering research using **clinorotation and other analog models**. Their rice seed studies revealed:

- **Improved yield**, **photosynthetic capacity**, and **nutritional content**.
- **97% seed viability**, even after simulated microgravity exposure.

This has implications for **space agriculture** and **climate-resilient farming**.

Human Physiology: Cardiovascular Adaptation

In 2023, **Prof. Vidyasagar and Dr. Sagar Jagtap** published a study in NPJ Microgravity (Nature) using a **360° rotating platform** to simulate human microgravity exposure. Results showed:

- Reversible changes in heart rate, blood pressure, and stroke volume.
- Validation of a **cost-effective terrestrial analog** for astronaut health studies.

🇮🇳 ***Wider Indian Contributions***

- **Dr. S. Ganapathy (IISc)**: Microbial responses for closed-loop systems.
- **Dr. R. K. Yadav (VIT)**: Stem cell adaptation under microgravity.
- **JNCASR Bengaluru**: Mechanotransduction and tissue modeling in altered gravity.

These contributions position India as an emerging hub in **space life sciences.**

8. Conclusion
Biophysics is not just a discipline it is a foundation for the future of science and technology. Whether in decoding the human brain, treating cancer, building life-support systems in space, or searching for extraterrestrial life, biophysics is the thread that weaves physics into biology for transformative outcomes.

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The **Axiom-4 Mission**, launched on **June 25, 2025**, is a milestone private spaceflight by **Axiom Space** in collaboration with **NASA**, **SpaceX**, **ISRO**, and the **European Space Agency (ESA)**. Representing India, astronaut **Shubhanshu Shukla** plays a pivotal role in this mission. Key experiments to be conducted in microgravity include studies on **muscle regeneration (*myogenesis*)**, **microalgae growth**, **crop seed germination**, **tardigrade resilience**, and **cyanobacteria behavior.**

Image Courtesy: Indian Space Research Organization

Astronomy: Resolution, Magnification and F-ratio of Telescope

Kiran Wani, PhD, Post-Doctorate Fellow
Indian Institute of Astrophysics, Koramangala, Bengaluru

जेव्हा केव्हा खगोलशास्त्राबद्दल चे public outreach चे program होतात आणि त्यात telescope मधून चंद्र, ग्रह, तारे दाखवले जातात तेव्हा बऱ्याचदा एक प्रश्न विचारला जातो. ज्या telescope मधून आम्ही बघतोय त्याची zooming power किती आहे आणि यातून किती दूर पर्यंत बघू शकतो. आपण रोज वापरत असणाऱ्या cellphones च्या camera मधे zoom करायचा एक option असतो, बहुदा त्यातून हा प्रश्न सहज पडत असणार. आपण आपल्या पहिल्या लेखात telescope आणि त्यांच्या प्रकारांबद्दल बद्दल जाणून घेतले. या लेखात आपण telescope च्या ह्या zooming power बद्दल चर्चा करणार आहोत. Resolution / Resolving Power, Magnification / Magnification Power, F-ratio या संकल्पना बद्दल आणि telescope च्या aperture size चा यांच्याशी काही संबंध असतो का आणि असेल तर तो कसा प्रभावित करतो या सर्वांबद्दल चर्चा करुयात.

Fig-1: Eagle Nebula. Left: Hubble Space Telescope (HST), Right: James Webb Space Telescope (JWST). Credit: ESA.

Fig-1 मध्ये डाव्या बाजूची image HST ची आहे आणि उजव्या बाजूची image JWST ची आहे. दोन्ही image वरुन लक्षात येईल की JWST च्या image मध्ये जास्त तारे दिसताय आणि ती जास्त detailed image आहे. या दोन images मधील फरक नेमका कोणत्या गोष्टींवर वर अवलंबून असतो ते बघुयात.

दोन objects ना resolved करुन बघता येईल का हे telescope च्या resolution वर ठरते. Resolution जितके जास्त तितके खूप जवळचे दोन objects वेगवेगळे बघू शकतो. Resolution हे दोन प्रकारचे असतात. एक Imaging/Spatial Resolution आणि दुसरे Spectral Resolution. Spectral resolution जितके जास्त तितके आपण एखाद्या objects च्या spectrum मधील सलग लागून असलेल्या दोन emission/absorption lines separate करुन identity करु शकतो. Spectral resolution हे telescope ला attached असलेल्या spectrograph वर अवलंबून असते. तर Imaging/Spatial resolution याला resolution limit या संकल्पनेने संबोधले जाते. Telescope चे resolution limit हे तीन factors वर ठरते.

1) Wavelength of Light
2) Telescope ची Aperture Size
3) Turbulence in Atmosphere

Resolution limit हे Rayleigh criteria ने असे define केले जाते:

$$\theta \text{ (in radian)} = 1.22\,\frac{\lambda}{D} \qquad (1)$$

यात θ हा दोन object मधील radial separation दर्शवतो, λ: wavelength of light, D: telescope च्या aperture size चा diameter.

$$1\text{ Rad} * \frac{(3600 \times 180)}{\pi} = 206265\text{ arcsec}$$

$$\theta \text{ (in arcsec)} = 206265 * 1.22 * \frac{\lambda}{D}$$

$$= 251643.3\,\frac{\lambda}{D} \qquad (2)$$

Eq-(2) मध्ये Visible light ची wavelength 550 nm consider केली आणि telescope चा 1 m diameter consider केला तर 0.138 arcsec चे resolution मिळते. म्हणजेच 1 meter optical telescope ने 0.138 arsec angular distance ने दूर असलेले दोन objects separate करुन बघू शकतो. Fig-2 मध्ये दाखवल्याप्रमाणे त्या दोन objects ना resolved करुन बघू शकतो. Wavelength कमी केली तर angular resolution ची value कमी होईल

म्हणजेच angular resolution अजुन better होईल. तसेच telescope च्या aperture size चा diameter वाढवला तर angular resolution वाढेल.

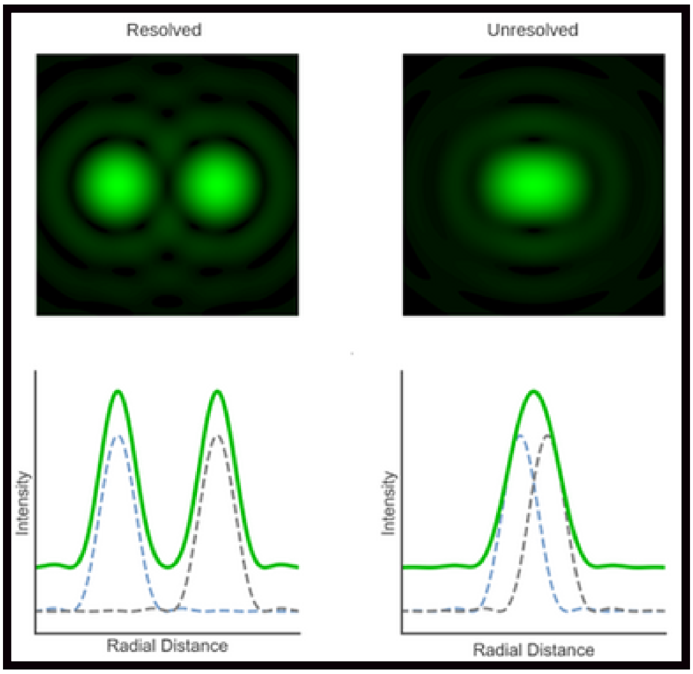

Fig-2 Point Spread Function and resolution of two point emitters.
Credit: https://www.edinst.co

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Hubble telescope साठी 0.05 arcsec चे angular resolution मिळते (with λ= 550 nm & D=2.4 m). हेच JWST साठी 0.07 arcsec इतके (with λ= 2 μm & D=6.5 m). यात JWST चा mirror HST पेक्षा 2.7 times मोठा असुन सुद्धा JWST च resolution HST पेक्षा थोडं कमी आहे. तर ते wavelength मुळे. JWST हा near-infrared आणि mid-infrared wavelength range मध्ये काम करतो तर HST हा mainly optical wavelength मध्ये. Shorter wavelengths मध्ये resolution अधिक चांगले मिळते.

Resolution limit वरुनच telescope ची resolving power किती ते ठरते. जितके जास्त angular resolution तितकी जास्त resolving power.

$$\textbf{Resolving Power} = \frac{1}{Angular Resolution} \qquad (3)$$

Angular resolution ची value जितकी कमी तितकी resolving power जास्त. Resolving power यात फक्त दोन गोष्टींवर अवलंबून आहे. जितका जास्त diameter तितका telescope जास्त light गोळा करु शकतो आणि तितकं जास्त त्याचं resolution आणि तितकी जास्त resolving power. आणि जितकी कमी wavelength तितकी जास्त resolving power. Radio आणि optical telescope ची aperture size सारखी ठेवली तर अधिक चांगलं resolution हे optical telescope ने मिळेल. त्या करताच radio telescope साठी light gathering area वाढवणे गरजेचे असते. जगभरातील मोठे high resolution चे radio telescope हे छोट्या radio telescopes च्या array ने बनवले जातात. उदा. पुणे जवळील खोडद येथे Giant Metrewave Radio Telescope (GMRT) साठी 45 m diameter चे 30 parabolic radio telescopes हे 25 square kilometer च्या परिसरात Y shape configuration मध्ये पसरले आहेत. GMRT चे 1.4 GHz frequency वर angular resolution 2 arsec इतके आहे. तर हेच दुसरीकडे X-ray telescope मध्ये 1 m diameter च्या aperture size ने angular resolution अधिक चांगले मिळते. जसे Chandra X-ray observatory चे angular resolution 0.5 arcsec इतके आहे.

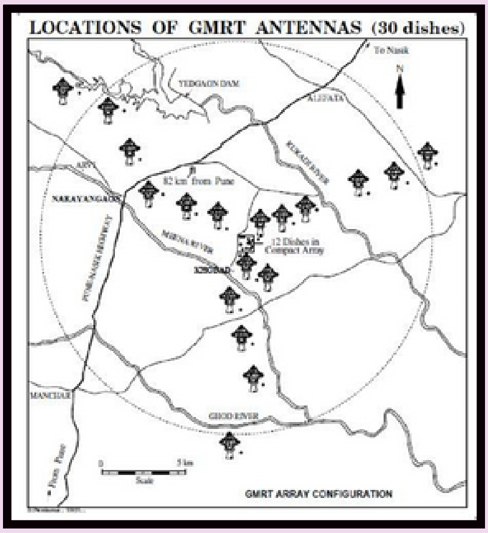

Fig-3: GMRT array configuration.
Credit: GMRT/NCRA-TIFR

Ground based telescopes चे resolution हे वातावरणातील turbulence मुळे कमी होते. त्यासाठी adaptive optics चा उपयोग केला जातो (उदा. Very Large Telescope, Keck

Telescope). Space based telescopes साठी atmospheric turbulence हा factor नसल्यामुळे त्यांची resolving power ही फक्त wavelength आणि aperture size वर अवलंबून असते.

Magnification: आता जो object आपण बघतोय त्याला आपण किती मोठं करुन बघू शकतो हे telescope च्या magnification power वर अवलंबून असते. Telescope मधून डोळ्यांनी बघण्यासाठी eyepiece ची गरज पडते. Telescope च्या focal length आणि eyepiece च्या focal length वर आपल्याला दिसणाऱ्या object ची image size ठरते. Magnification या दोन focal length चा वापर करुन define केलं जातं.

$$\text{Magnification} = \frac{\textit{Focal length of Telescope}}{\textit{Focal length of Eyepiece}} \quad (4)$$

Telescope ची Focal length जास्त आणि eyepiece ची focal length कमी असेल तर object ची image मोठी दिसेल. म्हणजेच magnification जास्त. जर telescope ला eyepiece न लावता camera वापरला तर primary lense/mirror च्या focal plane वर image तयार होईल. ह्या image ची size किती मोठी असेल हे telescope च्या focal length वर फक्त अवलंबून असेल. Primary objective lens/mirror ची focal length जितकी मोठी तितकी तयार होणाऱ्या image ची size मोठी. म्हणजेच magnification जास्त. जसं magnification वाढवत जाऊ तसं image size मोठी होत जाईल पण image धुसर होत होईल. Magnification जास्त पाहिजे असेल आणि image धूसर व्हायला नको असेल तर magnification सोबत aperture size पण वाढवायला लागेल.

F-ratio: Telescope च magnification आणि field of view, F-ratio वर अवलंबून असते. Telescope मधून आकाशाचा किती भाग आपण बघू शकतो याला field of view म्हणतात. Telescope मध्ये F-ratio हा महत्वाचा ठरतो आणितो असा define केला जातो:

$$\text{F - ratio} = \frac{\textit{Focal Length}}{\textit{Aperture Diameter}} \quad (5)$$

कोणत्या प्रकारचे objects telescope मधून बघायचे आहेत त्यावरुन F-ratio किती असला पाहिजे हे ठरते. जर छोटे objects बघायचे असतील (उदा. ग्रह) तर magnification जास्त आणि narrow field of view लागेल. यासाठी focal length जास्त आणि aperture size कमी असावी लागेल म्हणजेच F-ratio हा जास्त हवा. दुसरीकडे जर मोठे objects बघायचे असतील जसे nebulae आणि galaxies तर F-ratio हा कमी लागेल. म्हणजेच focal length कमी आणि aperture size जास्त. यात magnification कमी आणि wide field of view मिळेल. कमी F-ratio च्या telescope मधून कमी exposure time ने bright image मिळू शकते. HST f/24 focal ratio च्या configuration चा आहे तर JWST हा f/20.

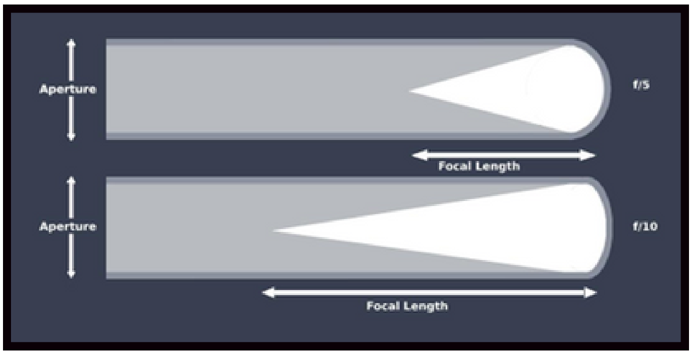

Fig-4: illustration of F-ratio.
Credit: https://www.telescopenerd.com/

तर एकंदरीत कोणत्या wavelength मध्ये object ला बघायचे आहे, कोणत्या प्रकारचे objects बघायचे आहेत, space-based telescope आहे की ground-based telescope आहे या सर्व गोष्टींवर telescope ची aperture size, त्याचे resolution, magnification and F-ratio ठरत असतो. तुम्हाला तुमचा स्वतःचा telescope घ्यायचा असेल तर ह्या सर्व गोष्टी तुम्हाला बघाव्या लागतील.

हे article जयंत नारळीकर सरांना dedicate करतो. खगोलशास्त्राची आवड अकरावीत असताना काही पुस्तकं वाचतांना निर्माण झाली. Prof. जयंत नारळीकर यांच्या विज्ञानकथा वाचून माझ्या कल्पना शक्तीला खूप वाव मिळाला आणि माझ्यात मनात खगोलशास्त्रा विषयी एक वेगळीच रुची निर्माण झाली. विज्ञान सोप्या शब्दांत लोकांपर्यत पोहचवण्याचा आणि समाजात वैज्ञानिक दृष्टिकोन रुजवण्याचे सरांचे प्रयत्न आपण पुढे घेऊन जाऊयात.

Weblinks:
https://www.telescopenerd.com/

Earth's Magnetic Memory!

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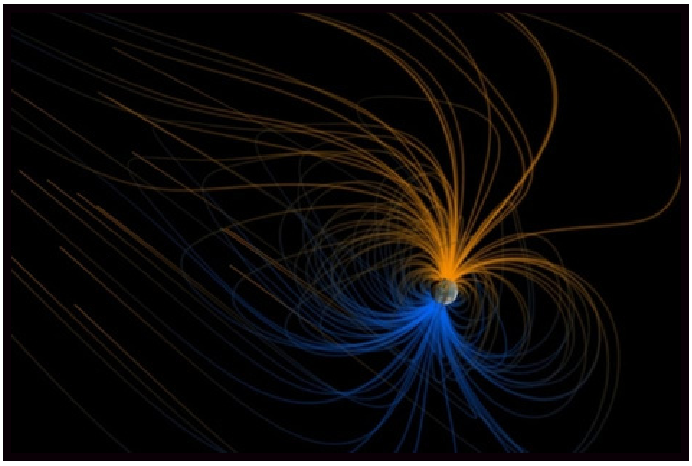

Introduction

Earth's magnetic memory is a fascinating chronicle of the planet's geomagnetic past, stored in rocks and sediments over millions of years. Like a planetary diary, this magnetic record offers vital clues about the history of Earth's core, plate tectonics, continental drift, and even life itself. Understanding this magnetic memory not only helps geologists reconstruct the planet's ancient geography but also aids scientists in forecasting future geomagnetic behavior, such as pole reversals and field weakening.

The Earth is encased in a giant magnetic field generated by the motion of molten iron and nickel in its outer core — a process known as the **geodynamo**. This magnetic field extends into space and protects life on Earth by shielding the planet from harmful solar radiation and cosmic rays.

The field has a roughly dipolar structure — similar to a bar magnet — with a magnetic north and south pole. However, unlike a stable bar magnet, Earth's magnetic field is dynamic: it drifts, fluctuates in intensity, and even reverses polarity over time.

Rocks Record Magnetic Information

When volcanic lava or sediments cool and solidify, tiny magnetic minerals within them (like magnetite) align with Earth's magnetic field at that moment in time. This process is known as **thermoremanent magnetization** in igneous rocks and **detrital remanent magnetization** in sediments. Once locked in, this alignment becomes a permanent record of the Earth's magnetic direction and intensity — a form of **paleomagnetism**.

These magnetic "fingerprints" remain intact unless the rock is reheated or altered, acting as time capsules that geologists can analyze.

Using Earth's magnetic memory, scientists developed a technique called **magnetostratigraphy**, which correlates magnetic signatures in sedimentary or volcanic sequences to the GPTS. This method allows precise dating of rock layers, especially in areas where other dating methods (like radiometric dating) are difficult. For example, magnetostratigraphy is widely used in studying oceanic crust, where symmetrical patterns of magnetic stripes on either side of mid-ocean ridges reveal the story of **seafloor spreading** and continental drift, confirming the theory of plate tectonics.

Applications and Importance

1. **Tectonic Reconstruction:** Paleomagnetic data help scientists reconstruct the past positions and movements of continents (paleogeography), crucial in understanding supercontinents like Pangaea.
2. **Climate and Evolution Studies:** By aligning geomagnetic records with fossil data and climate proxies, scientists explore links between magnetic field changes, climate shifts, and evolutionary milestones.
3. **Understanding the Core:** Variations in the magnetic field reveal information about convection patterns in Earth's outer core, which can influence geodynamics and core-mantle interactions.

4. Modern Relevance: As Earth's magnetic field weakens today and the north magnetic pole drifts rapidly, some speculate a future reversal may be on the horizon. Studying past behavior helps us understand what might happen and its potential effects on satellites, navigation, and power systems.

Earth's magnetic memory is a powerful, natural archive etched in rock, providing a unique window into the dynamic interior and surface evolution of our planet. It informs disciplines ranging from geology and archaeology to climatology and space science.

Unveiling the Mystery of Wormholes: Theoretical Gateways Through Spacetime

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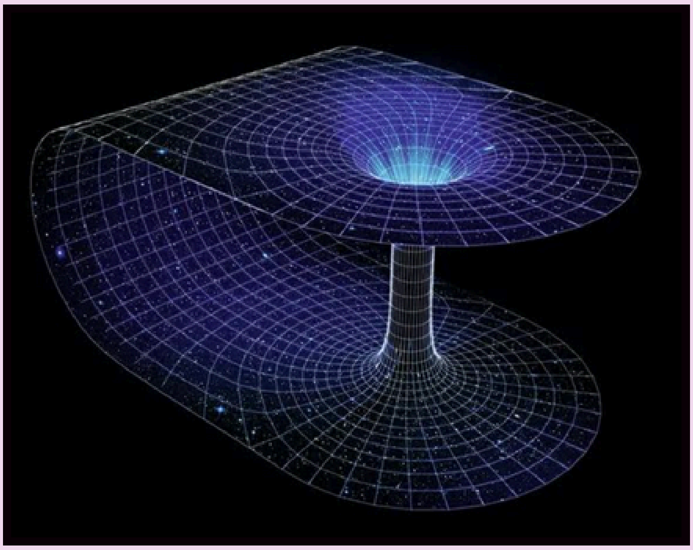
Introduction

Wormholes have long fascinated scientists and storytellers alike. These theoretical tunnels in spacetime could allow rapid travel between distant points in space—or even time. They emerge from solutions to Einstein's General Theory of Relativity and lie at the frontier of both theoretical physics and speculative fiction. In this article, we explore their scientific foundations, equations, challenges, and future possibilities.



What is a Wormhole?

A wormhole, or Einstein-Rosen Bridge, is a hypothetical tunnel-like structure connecting two separate points in spacetime. These points could lie far apart in space, time, or both. A wormhole can be imagined like a folded sheet of paper with two dots on it—bringing the dots together and poking a hole through the sheet forms a shortcut between them.

Einstein's General Theory of Relativity

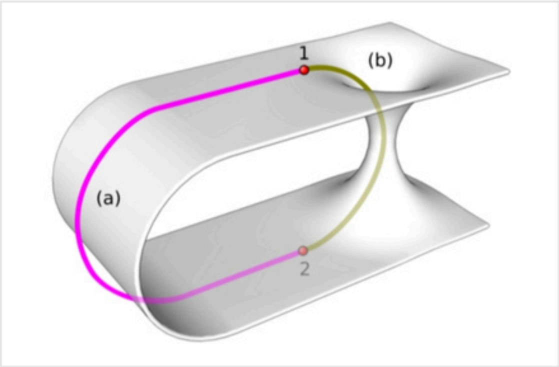
In 1915, Einstein's theory described gravity not as a force, but as the warping of spacetime by mass and energy. Massive bodies like stars and black holes create curves in spacetime, guiding the motion of other objects. Wormholes are special solutions to Einstein's field equations that reflect these curves.

Einstein-Rosen Bridges

In 1935, Einstein and Nathan Rosen found a solution to Einstein's field equations that described a bridge connecting two black holes. This Einstein-Rosen Bridge was the first theoretical wormhole. However, it is not traversable—if anything tries to pass through, it collapses instantly. Their solution used a transformation of the Schwarzschild metric to describe two symmetrical spacetime "sheets" joined at a throat (bridge). This avoided singularities (points of infinite density) and offered a model of neutral particles without introducing arbitrary singularities.

Traversable Wormholes and Exotic Matter

Later, physicists like Kip Thorne explored the idea of **traversable wormholes**—wormholes that remain open long enough for something to pass through. These require **exotic matter**, which has negative energy density and creates a repulsive gravitational effect. Although exotic matter hasn't been found, phenomena like the Casimir effect suggest that negative energy might be possible at quantum scales.



A wormhole visualized as a two-dimensional surface. Route (a) is the shortest path through normal space between points 1 and 2; route (b) is a shorter path through a wormhole.

Quantum Physics, Time Travel, and Modern Theories

Wormholes may permit time travel, depending on how their mouths are moved or influenced by gravity. In 1988, Thorne and Yurtsever suggested that accelerating one end of a wormhole could enable backward time travel. However, this would only allow returning to the time when the wormhole was first created.

The **ER = EPR** hypothesis by Juan Maldacena and Leonard Susskind proposes that wormholes are equivalent to entangled particles, linking quantum physics with general relativity.

Spacetime Visualization and Wormhole Geometry

To visualize a wormhole, imagine folding space so that two distant regions meet. A wormhole is like a tunnel connecting them. In higher dimensions, this geometry becomes complex, but the analogy helps us grasp how wormholes could link far-flung areas of the universe.

Related Concepts

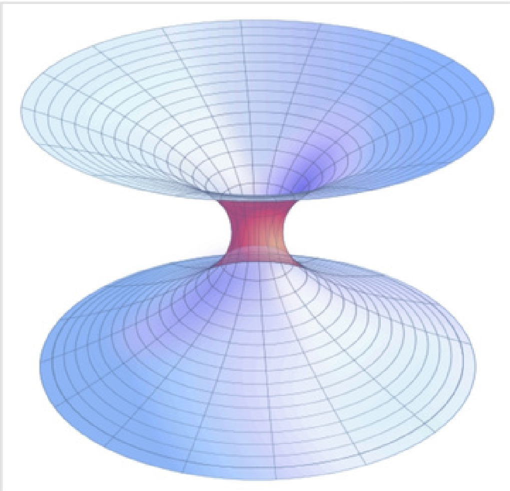
- **Black Holes:** Regions with gravity so strong that not even light can escape.
- **White Holes:** Theoretical opposites of black holes that expel matter and cannot be entered.
- **Event Horizon:** The boundary beyond which nothing returns from a black hole.
- **Time Dilation:** The slowing of time near massive objects, essential in black hole and wormhole physics.
- **Alcubierre Drive:** A theoretical faster-than-light engine that contracts space in front and expands it behind a spacecraft, resembling the concept of a wormhole.

Time Machines and Causality

Wormholes could, in theory, become time machines if their ends are moved relative to each other, exploiting time dilation. This raises the possibility of **closed timelike curves (CTCs)**, but may result in **causality violations**—logical paradoxes such as altering past events.

Challenges and Limitations

- Exotic matter may not exist naturally.
- Quantum effects might destabilize wormholes.
- Real-world traversability is uncertain.
- Wormholes might violate causality (the principle that cause precedes effect).



"Embedding diagram" of a Schwarzschild wormhole

Quantum Computing and Deep Learning

Recent studies use deep learning and quantum algorithms to find and analyze wormhole solutions. These tools simulate spacetime geometry, test energy conditions, and accelerate the search for feasible traversable wormhole structures.

Einstein's Field Equations and Solutions

At the heart of General Relativity lie Einstein's field equations:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = (8\pi G/c^4)\, T_{\mu\nu}$$

Where:

- **$G_{\mu\nu}$:** Einstein tensor (describes spacetime curvature)
- **Λ:** Cosmological constant (accounts for dark energy)
- **$g_{\mu\nu}$:** Metric tensor (describes the geometry of spacetime)
- **$T_{\mu\nu}$:** Energy-momentum tensor (describes energy and momentum in spacetime)
- **G:** Gravitational constant
- **c:** Speed of light

Solution Examples:

- The **Schwarzschild solution** describes a non-rotating black hole.
- The **Morris-Thorne metric** describes a traversable wormhole:

$$ds^2 = -c^2dt^2 + dl^2 + r(l)^2(d\theta^2 + \sin^2\theta\, d\phi^2)$$

Where **r(l)** is the shape function determining the wormhole's spatial geometry.

Current Research and Future Prospects

Researchers are actively investigating quantum gravity, string theory, and spacetime topology to better understand wormholes. No direct evidence has been found yet, but breakthroughs in high-energy physics or advancements in telescope technology may eventually reveal signs. Theoretical models, simulations, and AI continue to expand our knowledge in this field.

Conclusion

Wormholes remain one of the most captivating ideas in theoretical physics. While still speculative, they open doors to new ways of understanding space, time, and the universe. With ongoing research in quantum mechanics, deep learning, and cosmology, humanity may one day unlock the secrets of these enigmatic spacetime tunnels.

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Illuminating Life: The Physics Behind Modern Microscopy

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In the world of science, the tiniest things often hold the biggest secrets. Cells, proteins, DNA, all essential for life. It exists below what our naked eyes can perceive. That is where Physics steps in and shaking hands with Biology, to help us evolve the unseen world. The **biophysical imaging** techniques are continually evolving to unveil these microscopic wonders. At the heart of this lies a microscopy - a technique that has evolved from simple optical microscopes to cutting edge technologies powered by nanomaterials and quantum optics nowadays.

The Evolution of Microscopy

Traditional optical microscopy, while revolutionaries in its time, it is limited by the diffraction of light, capping resolution at approximately 200 nm. This limitation hinders our ability to observe surface morphologies at the microscopic level. However, advancements in super resolution microscopy have shattered this barrier. Techniques such as **Stimulated Emission Depletion (STED), Photoactivated Localization Microscopy (PALM), and Stochastic Optical Reconstruction Microscopy (STORM)** manipulate the behavior of fluorophores to achieve resolutions well below the diffraction limit. These advances aren't just technical marvels, they have opened doors to understand biological processes in real time, at the microscopic level.

Nanoparticles: Enhancing Biological Imaging

Nanotechnology has introduced a plethora of tools to enhance imaging. **Fluorescent nanoparticles which illuminate visible light on energy bombardment**, including quantum dots and upconverting nanoparticles (UCNPs), offer brighter and more stable signals compared to traditional dyes. These nanoparticles can be engineered to target specific cellular components, allowing for precise imaging of biological processes.

Moreover, **gold nanoparticles** have been utilized in **photothermal optical microscopy**, a technique that detects non-fluorescent labels based on their heat absorption properties, providing an alternative and very effective method for fluorescence-based methods. These tiny particles interact with light in unique ways, providing brighter, more stable signals than traditional dyes. Some of them can even penetrate deep tissues, helping us to view surface of internal cellular structures in living organisms in real time.

The Physics of Contrast:

Not all imaging relies on fluorescent tags. In most of the cases, physical properties like **phase and interference** are used to generate contrast. **Phase-contrast and Differential Interference Contrast (DIC) microscopy** can highlight transparent, living cells without staining them. These subtle techniques, based on light wave behavior allows researchers to observe light in the most natural state.

Watching Life in Motion:

What makes these imaging tools truly special is their ability to capture **live dynamics**. We are no longer limited to fixed snapshots. Today, researchers can watch migration of mitochondria, signaling proteins gather at a particular place lively. This temporal dimension has added richness to our understanding of life's processes, something classic biology couldn't provide alone.

Applications and Future Prospects

The integration of nanomaterials in microscopy has profound implications:

- **Disease Diagnosis:** Enhanced imaging allows for early detection of diseases at the cellular level.
- **Drug Delivery:** Tracking nanoparticles aids in understanding and improving targeted drug delivery systems.
- **Neuroscience:** Observing neuronal activities in real time contributes to our understanding of brain functions and disorders. As we continue to merge the principles of Physics with Biological sciences, the potential for discovery is boundless. The microscopic world once hidden, is now illuminated, offering insights that could revolutionize medicine, biology and beyond.

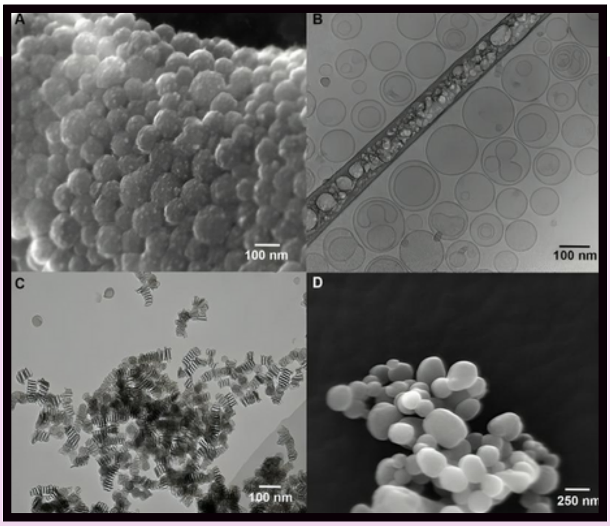

Figure 1: Electron microscope images of nanoparticles. A) Scanning electron microscopy (SEM) image of PLGA nanoparticles; B) Cryo-EM image of liposomes; C) Transmission electron microscopy (TEM) image of MSNs; D) SEM image of GNPs.

Schematic illustration of NPs used in fluorescence microscopy and comparison of various imaging modalities are shown in Figure 3. The Figure 3(a) (green panel) illustrates simplified light-paths to implement confocal imaging, and different super-resolution techniques and their variants.

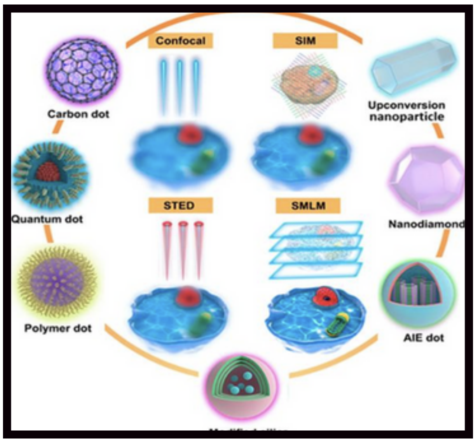

Figure 2: Super-resolved biological samples using imaging microscopy

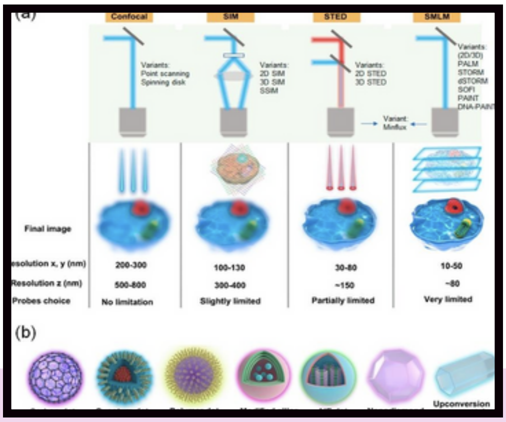

Figure 3: Schematic illustration of NPs used in Fluorescence microscopy and its comparison.

Bottom row: In conventional confocal laser scanning microscopy (CLSM) the image information is gathered sequentially by rostering a focused excitation laser beam across a sample plane (first column). In super-resolution microscopy (SRM), the fluorophores are distinguished by switching between discernible fluorescent states, e.g., on- and off- states. **2nd column:** in structured illumination microscopy (SIM), this is achieved through illumination with striped patterns. The spatial modulation of the excitation patterns generates frequency beats with spatial frequencies in the sample. The resulting widefield fluorescence image exhibits so-called Moiré fringes that encode high resolution detail in the low frequency beat patterns. Raw images are collected for different orientations of the illumination pattern. Through mathematical reconstruction, a 2-fold enhancement in spatial resolution can be obtained over wide-field microscopy. **3rd column:** in stimulated emission depletion microscopy (STED), fluorophores are returned to an off state by a doughnut shaped beam surrounding the excitation beam. As a result, only fluorophores near the center of the excitation beam emit signal, creating an excitation point spread function (PSF) that is narrower than in the absence of the depletion beam and thus enhanced resolution. Last column: in single-molecule localization microscopy (SMLM), super-resolution is achieved through the sequential imaging of individual fluorophores and inferring the position of emitters through estimation of the centroids of the emission PSFs from individual fluorophores. Photo-controllable fluorophores are required that can be cycled between fluorescent on- and off- states during illumination. Note that the resolution stated for the individual techniques are indicative only and may vary with experimental setups and fluorophore properties. SSIM, saturated structured-illumination microscopy; PALM, photoactivated localization microscopy; dSTORM/STORM, direct stochastic optical reconstruction microscopy/stochastic optical reconstruction microscopy; SOFI, super resolution optical fluctuation microscopy; PAINT, points accumulation for imaging in nanoscale topography; MINFLUX, minimal emission fluxes. Figure 3(b) Schematic makeup of various fluorescent NPs, including carbon dot, quantum dot, polymer dot, modified silica nanoparticle, aggregation-induced emission (AIE) dot, nanodiamond, and upconversion nanoparticles.

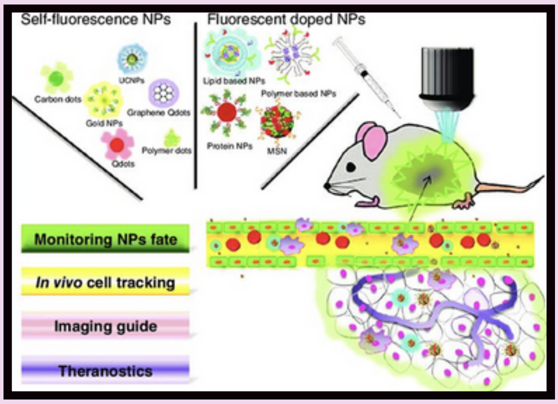

Figure 4: Various fluorescent nanoparticles for bioimaging MSN: Mesoporous silica nanoparticles; NP: Nanoparticles; UCNP: Up-conversion-nanoparticles.

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Do You Know ?

Zooming Misconception

- People often confuse zooming with magnification, but in optics, magnification doesn't always improve resolution.

Magnetic Flip

- Earth's magnetic field has flipped its polarity many times in history the North and South poles switch places roughly every 200,000–300,000 years!
- The last full magnetic reversal happened about 780,000 years ago, known as the Brunhes–Matuyama reversal and we're overdue for another one!

Casual Paradox:

- Some solutions suggest wormholes might allow for time travel but only to the moment the wormhole was created, leading to mind-bending causal paradoxes.

Upconversion Nanoparticles

- Upconversion nanoparticles (UCNPs) absorb low-energy infrared light and emit visible light, making them ideal for deep tissue imaging.

The Therapeutic Power of Physics: Magnetic Fluid Hyperthermia in Oncology

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1. Introduction

Cancer comes in over 100 kinds and symptoms, making it one of the leading causes of death globally. Addressing this issue has become major health concern. More than 52,900 people are diagnosed by cancer every single day, and more than 27,000 people pass away due to this deadly disease. According to predictions, there would be 16.2 million deaths caused by cancer and 28 million new cases worldwide by 2040. The World Health Organization (WHO) reported that in 2022, cancer was a significant cause of death around the world, responsible for around one in every six fatalities and impacting almost every family. Cancer incidence and mortality rates are projected to rise by almost 77% by 2050, putting additional strain on communities, people with disabilities, and health systems. As researchers gain a deeper insight into the fundamental physics and biological interactions, Magnetic Fluid Hyperthermia (MFH) is becoming a promising addition to cancer treatment strategies. By utilizing core principles of magnetism and thermodynamics, MFH brings new optimism to patients and healthcare providers, enhancing treatment results and improving quality of life. This innovative method highlights the transformative role of physics in medicine, opening the door to new therapies that can significantly impact patients care[1].

1.1. Cancer treatment challenges

At present, the cancer treatments available in clinical settings include chemotherapy, radiotherapy, and surgical removal. However, these treatment options come with several disadvantages. In the process of chemotherapy, drugs are administered into the body to eradicate cancer cells. While chemotherapy effectively targets these malignant cells, it may also lead to unwanted effects, including weakening the immune system, increasing susceptibility to infection, causing digestive issues, and potentially harming the nervous system.

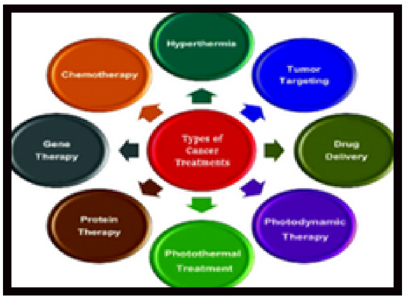

Fig. 1 Types of cancer Treatment

Radiotherapy is another approach that employs radiation energy to eliminate tumors. However, due to the difficulty in precisely targeting the entire tumor, the radiation may not completely eradicate it, and the surrounding organs in the radiation area might lose their function. Surgery can only be effective if the precise locality of the cancer is accessible. In other words, surgical intervention is not an option for tumors that are deep-seated inside the body. Additionally, surgery carries the risk of infection and may lead to complications affecting nearby organs. Figure 2 depicts a briefing on surgery, chemotherapy, and radiation therapy negative effects[2].

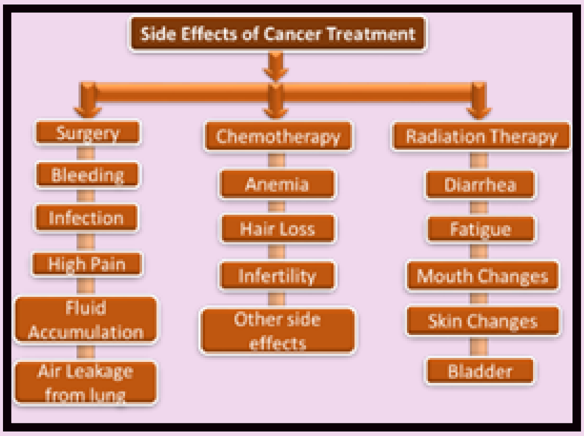

Fig. 2 Side effects of non-conventional cancer treatments

1.2. Thermotherapy is an innovative solution for oncological treatment

Early detection and treatment can lead to the cure of most cancers. To lower cancer-related deaths worldwide, it is essential to focus on precise, personalized treatments and to continue investing in cancer research. Thermotherapy, a promising approach, involves using heat to eliminate cancer cells. This method includes two primary heating techniques: thermal ablation and hyperthermia. Thermal ablation is a medical technique that employs extremely high temperatures to intentionally damage or destroy specific tissues, such as cancerous tumors. However, it requires careful administration to avoid damaging nearby healthy tissues. Hyperthermia, a highly effective form of thermotherapy, which entails increasing the internal body temperature from the typical 37 °C to a range of 41 to 45 °C in one or more areas. Considering the ability to target cancer cells specifically while preserving healthy surrounding tissue, heating tumors to this temperature range can improve the success rates of chemotherapy and radiation therapy.

2. Therapeutic Power of Physics

Physics is a scientific field focused on comprehending and applying the core principles that dictate the physical, chemical, and biological processes in nature. It has been instrumental in the evolution and provision of sophisticated, accurate, and targeted healthcare services at contemporary cancer treatment centers. Progress in medical physics has greatly improved the accuracy and effectiveness of cancer therapies. These developments improve the quality of life for cancer patients by lowering side effects and improving patient outcomes by providing more individualized and efficient treatments.

The application of nanoscale materials, especially magnetic nanoparticles (MNP), is a significant focus in the fields of medical and life science research. When materials are scale down to the nanoscale (1–100 nm), they display distinct size-dependent physical, chemical, and biological characteristics. One of the most useful applications of nanoparticles in medicine is the control and utilization of their magnetic characteristics for cancer diagnosis and treatment. Magnetic nanoparticles can selectively attach to target cells or tissues and carry out their therapeutic functions by combining high saturation magnetization with a surface that has been suitably functionalized. Specifically, iron oxide nanoparticles are being extensively studied for their potential to effectively destroy cancerous cells via using magnetic hyperthermia therapies.

2.1. Magnetic induction heating system

The magnetic induction heating setup, featuring a solenoid coil, generates a magnetic field inside the coil. The coil, along with other design elements, consists of six turns constructed from sections of cylindrical copper plate, enhancing its performance compared to a similarly sized solenoid. In this process, a 2.5 mL microcentrifuge tube are filled with MNPs at different concentrations (e.g. 5, 10, and 20 mg/ml), dispersed in 1.5 ml of ultrapure water (basefluid), and hold in place by a holder in the middle of the coil without damaging the walls or disrupting the sample and exposed to a frequency of 280 kHz. An internal liquid-cooled system are employed to maintain the coil at equilibrium with ambient temperature. The temperature variation of ferrofluids are observing under a magnetic field strength (AC) of 4.0 kA/m at varying percentages. The increase in sample temperature are tracking and recognized every 30 seconds using thermal detection systems with compact heating capabilities. The heat was produced by a specific loss mechanism under the influence of an alternating magnetic field, which is categorized into hysteresis and relaxation losses (Neel and Brownian losses). Cancer cells are more susceptible to heat stress than normal cells, making them responsive to induced heating. Hyperthermia can be applied to tumor cells using a heating coil with specific shape and size, along with high-frequency and strong magnetic field intensities. This targeted approach leverages the vulnerability of cancer cells to heat, potentially enhancing treatment efficacy.

Circulating eddy currents are induced within a metal part when it is put into an inductor and exposed to the magnetic field. The eddy currents oppose the electrical resistivity of the metal, creating precise and localized heat without any direct contact between the component and the inductor.

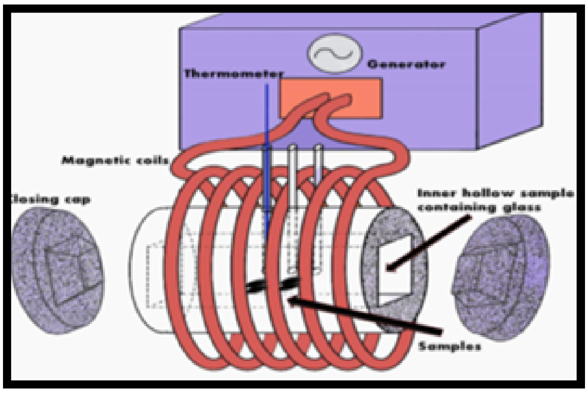

Fig 3. Induction heating setup

The Joule effect defining the link between heats created by electrical current carried through a conductor, occurs with both magnetic and non-magnetic parts. Second, hysteresis describes the internal friction that occurs when magnetic elements shift within the inductor, causing additional heat to be produced in these magnetic components. Magnetic materials inherently resist the rapidly changing magnetic fields of inductor, and this opposition leads to internal friction that generates heat.

3. Magnetic Fluid Hyperthermia (MFH): A novel approach to cancer treatment

The fundamental concept of MFH involves the transformation of magnetic energy into heat energy by MNPs distributed within a tumor. The process of raising the temperature of specific organs or tissues to between 41°C and 46°C, primarily for cancer treatment, is known as `Hyperthermia'[2]. There are three main clinical methods for applying elevated temperatures: local hyperthermia, regional hyperthermia and whole-body hyperthermia.

Hyperthermia faces challenges in selectively heating tumors without harming healthy tissue. Traditional methods risk overheating and uneven temperature distribution. Magnetic nanoparticle-mediated hyperthermia offers a promising solution, using MNPs to target tumor cells and generate heat through an alternating magnetic field, potentially overcoming these limitations. MNPs, typically made of iron oxide, are taken up by cancer cells and then exposed to an alternating magnetic field, causing them to vibrate and generate localized heat (42°C-45°C) that kills cancer cells while minimizing harm to healthy tissue.

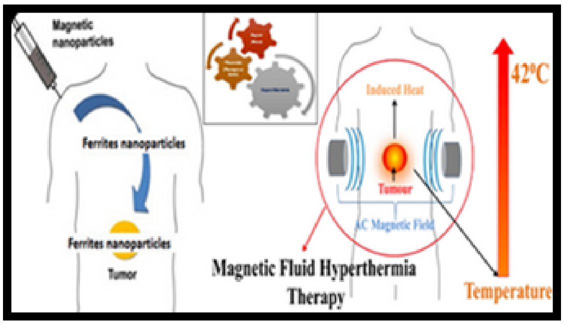

Fig. 4. Schematic representation of clinical trial of magnetic fluid hyperthermia therapy.

3.1. Key elements contributing to MFH includes:

i. Magnetic Nanoparticles (MNPs): Iron oxide-based, influencing heating efficiency and biocompatibility through size, shape, and coating.

ii. Alternating Magnetic Field (AMF): Induces heat generation through magnetic moment rotation/relaxation, with frequency and amplitude determining efficiency and safety.

iii. Heat Generation Mechanisms: Governed by Néel relaxation (smaller MNPs) and Brownian relaxation (larger MNPs).

iv. Hyperthermia: MNP-generated heat damages/kills cancer cells (41°C-45°C) while sparing healthy tissue.

v. Specific Absorption Rate (SAR): Quantifies heat generated per unit mass/time, crucial for optimizing heating efficiency and determining MNP/AMF parameters.

3.2. Advantages of MFH

The MFH therapy offers several benefits and advantages in the treatment of cancer. One of the primary advantages of MFH is its minimally invasive nature, which reduces the risk of complications and side effects associated with traditional cancer treatments. Additionally, MFH selectively targets cancer cells, minimizing damage to healthy tissues and preserving organ function. This targeted approach also enables the treatment of tumors in sensitive or hard-to-reach areas, such as the brain or spine. Additionally, to increase the therapeutic effect and boost the results for patients, MFH can be used in conjunction with other cancer therapies including chemotherapy or radiation therapy.

4. Conclusion

In conclusion, the therapeutic power of physics in MFH has been effectively utilized to create a targeted and effective cancer treatment. By combining the principles of magnetism and thermodynamics, MFH therapy has shown promising results in selectively destroying cancer cells while protecting normal cells and tissues. As research continues to advance our understanding of the underlying physics, the potential applications of MFH are expanding, offering a brighter outlook for patients and medical professionals. An innovative combination of precision, efficacy, and minimal invasiveness, MFH is poised to become an increasingly important component of cancer treatment protocols, demonstrating the vital role that physics plays in developing innovative therapeutic strategies. The potential impact of providing a targeted and minimally invasive treatment option, MFH has the potential to enhance patient care, minimize adverse effects, and boost quality of life. Providing advantages in treatment effectiveness, healthcare affordability, and patient well-being, MFH is an exciting and promising development in the field of oncology.

5. Future outlook

As we look to the future, the therapeutic power of physics in MFH holds great potential ground breaking opportunities in oncology. Despite constant challenges and limitations, research and technological developments are being implemented to get beyond these barriers and open the door for the broad use of MFH in clinical practice. Clinical trials for MFH are currently being conducted in countries such as Austria, China, Germany, Japan, Switzerland, Netherlands and North America. However, it is not well-known in India. As we continue to explore the boundaries of physics and medicine, it is clear that MFH will play an increasingly important role in the fight against cancer, supporting better healthcare experiences. Aligning with healthcare priorities of quality, safety, and efficiency, the future of MFH in oncology is bright, and its impact is expected to resonate for years ahead.

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Do You Know ?

Magneto-Thermal Therapy:

- In cancer treatment, magnetic nanoparticles are introduced into the tumor. When subjected to alternating magnetic fields, these particles heat up and can selectively kill cancer cells — this is known as hyperthermia therapy.

Nanotechnology In Agriculture: An Innovative Approach

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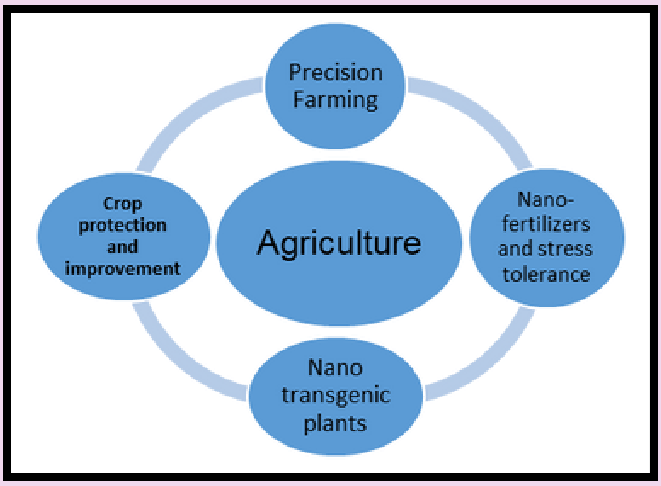
The era where we are living today can be considered as the 'Nano Age', since every aspect of life has a touch of nano, be it the cosmetics, the textiles, the appliances we use, the gadgets, the food, or the environment we live in; nanomaterials are already in us, on us and around us.[1] Nanomaterials have unique physicochemical properties and provide versatile scaffolds for surface functionalization with biomolecules. For this reason, more recently, the field of nanotechnology is gaining an increased interest in plant sciences, especially in plant biotechnology and agriculture.[2] Recently, various metal (Ag, Au) and metal oxide (ZnO, TiO_2, Fe_2O_3, CuO)nanoparticles have been extensively used in agriculture and the broad aspects are given in the diagram below

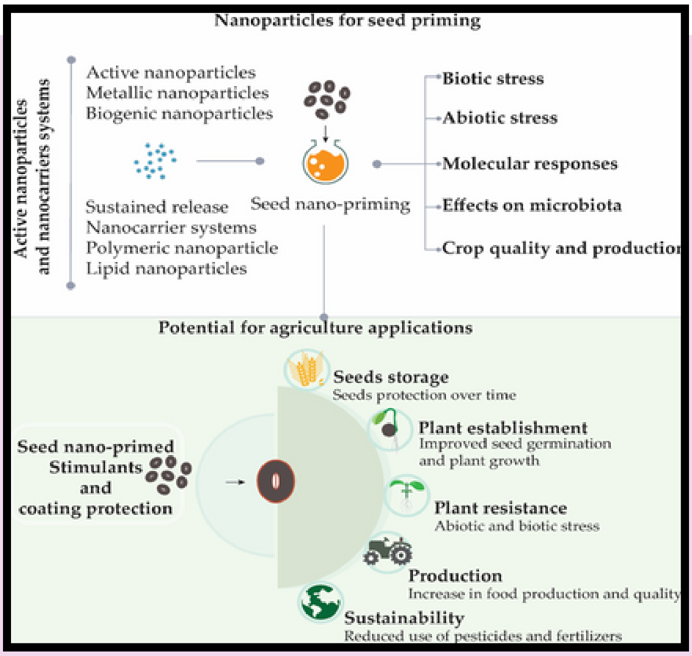


This article throws the light on some of the less known applications of nanoparticles in agriculture.

Nanopriming:

Seed priming is the process of regulating germination by managing the temperature and seed moisture content in order to maximize the seed's potential. Seed priming techniques can vary with different type of seeds so as to synchronous germination, higher mean germination rate and coefficient variation of mean germination time, which maximized the chances of uniform establishment in seedling stages.

Nanopriming is a type of priming of seeds using various nanoparticles at optimum concentration and time duration. Recently, Song and He,[3] have highlighted that nanopriming synchronizes seed germination by activating metabolic enzymes such as amylase, protease and lipase. Priming can induce reactive oxygen species (ROS) production to promote early embryo growth and development and slowly penetrate the seed to modulate metabolic processes. Seed pretreatment with nanoparticles not only promotes seed germination but also affects seedling uniform establishment in seedling stages.



Periera et al,[5]

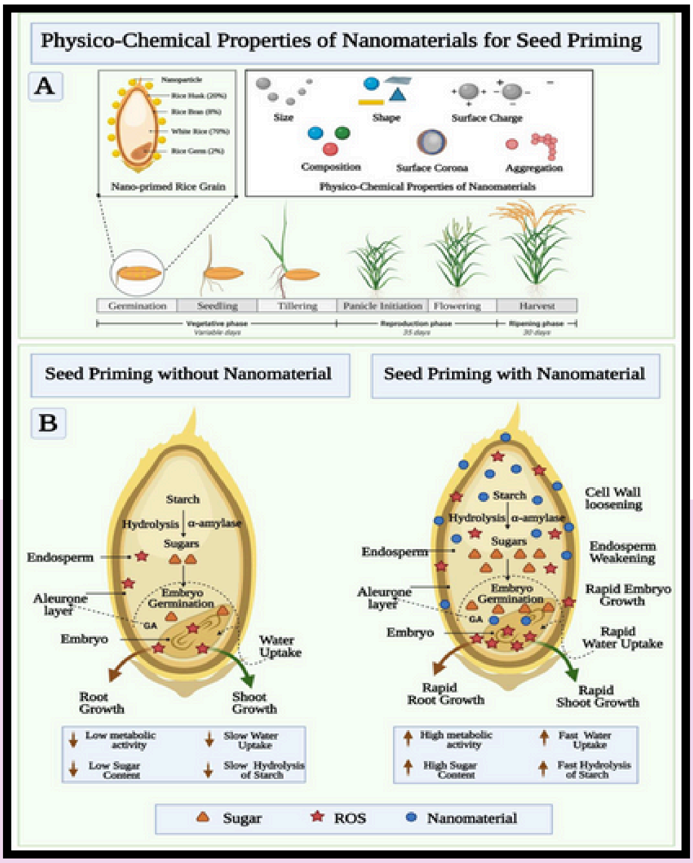
This process involves the general steps such as:

- Soaking seeds in nanoparticles solution
- Facilitate the penetration of nanomaterial inside the seed leading to increase in water uptake
- Due to high surface to volume ratio nanomaterials impart physicochemical properties which alter the

metabolic activity of seeds

- Influences rapid germination of seeds which produces to better quality seedlings leading to uniform emergence of crop stands.

The exact mechanism with change in physico-chemical characteristics inside the seed has been illustrated in the figure which gives an idea of the biochemical and molecular changes that occurred during uptake of nanoparticles till germination and final yield.



Shelar et. al., 2021[6]

Future Direction:

Thus, nanopriming is a promising technique which has a great potential to improve seed germination percentage, rate of seed germination, enhance seedling growth, to combat against biotic and abiotic stress and therefore directly or indirectly involved in increasing crop yield. However, further research is needed

1. To optimize nanoparticle formulations that is attributed to find out the exact concentration (in ppm) with less or no toxicity.
2. To understand the exact biochemical and molecular or genetic mechanism by which nanoparticles interact with seeds and plants.
3. To aware and develop their practical applications so as to scale up strategies.
4. To assess the environmental impact and interaction.

Postharvest Management

In new era, nanoparticles are being explored to develop innovative solutions for postharvest management such as

1. **Preservation:** Nanoparticles can be used in coatings or in packaging materials that probably used to extend the shelf life of fruits and vegetables especially perishable items.
2. **Quality management:** Nanoparticles based sensors are available in markets that can detect the changes in food quality, contaminants, etc
3. **Antimicrobials:** Various nanoparticles (Ag, Au, ZnO, etc.) have been proved as a good antimicrobial and hence can help to prevent the spoilage and contamination of food products.
4. **Edible coatings:** They can be incorporated into packaging materials, sprayed in specific concentrations or used as coatings to enhance food safety and quality

Various biosynthesized nanoparticles like Silver, Zinc oxide, Chitosan, etc have been used and tested for their use in post-harvest technologies however, further research is essential to ensure safety, toxicity, efficacy and Government regulations.

Apart from these, nanoparticles have various applications in agriculture sector such as Plant protection, Plant growth promotion, Stress tolerance, Disease detection, Nutrient delivery, Seed and pollen germination, Plant breeding and Bio and soil remediation, etc.

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Do You Know ?

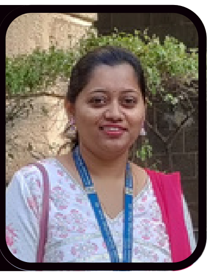
Nanoparticle Properties:

- Nanoparticles exhibit quantum confinement, large surface area-to-volume ratios, and unique electromagnetic interactions, making them highly reactive and effective at very small scales.

Electrostatic Interaction:

- Many nanoparticles used in nanopriming rely on electrostatic interactions with seed coatings — similar to Coulomb forces studied in classical physics.

The Role of Magnetic Field in Biophysics



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1. Introduction

Magnetic field play an essential role in various scientific and technological applications. From influencing electrical currents and magnetized materials to their impact on biological systems, these fields are a fundamental force in nature. In everyday life, we encounter magnetic effects through permanent magnets that attract iron and interact with other magnets. But beyond their practical applications, magnetic fields are deeply connected to the broader principles of electromagnetism.

2. Effect of Magnetic Field on Biological Systems

i. Animal navigation and geomagnetism:

Many animals possess the ability to ***sense geomagnetic field***, aiding them in behaviours like ***migration*** and ***navigation***. Birds, fishes, and certain insects rely on Earth's natural magnetic field to guide their movements.

ii. Impact of magnetic field on health:

However, magnetic field have raised concerns regarding their effects on biological health. Some studies suggest that exposure to magnetic field from devices such as ***mobile phones*** and ***high-voltage power lines*** could have ***adverse health effects***. But do these weak fields truly influence biological processes?

iii. The radical pair mechanism and magneto - biology:

One of the most promising explanations is the ***radical pair mechanism***, which suggests that weak magnetic field may impact biology at a quantum level. This mechanism is widely observed in ***protein reaction processes*** and has proven valuable in understanding radical driven biological mechanisms. The field of ***magneto-biology***, a subdiscipline of ***biophysics***, explores how external influence biological systems. At various levels—from nano (atoms and molecules) to macro (human physiology)-magnetic fields can trigger ***significant biological reactions.*** However, substantial effects usually occur under ***strong and prolonged exposure.*** Interactions at the ***molecular level***, particularly involving ***paramagnetic particles*** and ***unpaired electron spins,*** help explain how magnetic fields influence biological processes.

It highlights the structural changes that may occur at the ***molecular level,*** providing insight into how weak electromagnetic forces might biological functions.

3. Material and Methods:

The present study deals with the effect of magnetic field on protein. Proteins were exposed to around 300 Gauss static magnetic field using bar magnets.
The present study is design to evaluate the effect of static magnetic field on BSA proteins.

- ***Protein used: Bovine Serum Albumin (BSA)*** Bovine serum albumin fraction V was purchased from Sigma is used for study of denaturation process.
- ***Solvent:*** Distilled water is used for all the experiments

3.1. Instrumentation: The absorption spectra were recorded using JASCO 670 spectrophotometer. And Transmission spectra were recorded using JASCO 6100 spectrophotometer.

3.2. Method: Powder BSA is used further purification. BSA solutions were prepared using distilled water as base solution by direct mixing method. In order to get uniform solutions and accurate results, all solutions were freshly prepared.

3.3. Experiment: A static magnetic field around 300 Gauss (0.03T) as 1T $=10^4$ Gauss produce by bar magnets was used to expose BSA protein. Approximately, 3 mg of BSA protein solution (3 mg/ml) prepared using distilled water was used for the experiment.

The experimental set up consist of two bar magnet 4 cm in length and 1cm in width mounted on a stand and a test tube with 1cm diameter and 10 cm in length was place at the center of these two magnets. The experiment was conducted across varying durations such as, 10, 20, 30, 60 and 120 minutes which gives different results depending on the specific time period.

4. Result and Discussion:

Magnetic field effects on biological systems causes changes in protein conformation at molecular level which results in changes in physio-chemical properties. To determine the changes in BSA protein due to magnetic field UV visible and FTIR spectroscopies are used.

a) UV-Visible Spectra

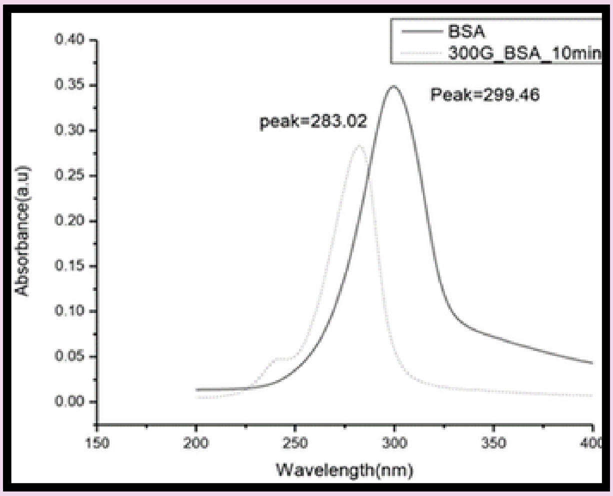

Figure 1: UV-visible Spectra a) BSA control b) BSA expose to 300 G magnetic field

UV-visible absorption spectra shows the conformational changes in tertiary structure of BSA protein, particularly change in local environment of polypeptide chain. The absorption spectra of BSA in presence and absence of magnetic field illustrated in figure (1). BSA protein absorb UV light and shows two distinct peaks. The peak centered at 299.02 nm is a result of absorbance by aromatic ring portion of their structures (try, trp; etc) , while the peak after exposing to 300 G magnetic field at 283.12 nm is caused by absorbance of peptide and carboxylic acid moieties in the compounds (N-terminal peptide as –NH-CHR-COOH and C- terminal peptide as NH_2 – CHR-CO-).UV absorption for BSA protein solution shows the peak at 299.02 nm and 283.12 nm with hyperchromic blue shift and red shift respectively.

Table 1: Peak position of BSA

Sr. no	Control BSA	BSA 10 min	BSA 20 min	BSA 30 min	BSA 60 min	BSA 120 min
Peak (nm)	299.2	283.12	283.12	283.12	283.12	283.12
Abs (a.b.)	0.35	0.43	0.43	0.43	0.43	0.43

The band of 299.02 nm is related to electronic transition (n to p*) corresponds to aromatic amino acid tyrosine, phenyl alanine and tryptophan and absorption at 283.12 nm (p to p*) is related to electronic transition of amide groups of peptide bonds. The shows increase in absorption intensity after exposing 300 G magnetic field.

There is negligible shift in absorption wavelength as shown in table (1) changes in tertiary structure were examine by second derivative of UV absorption spectroscopy which is sensitive to polarity and thus the solvent exposure, of local environments of aromatic residue with increase in magnetic field it shows significant change in position of peaks due to change in local environment around tryptophan and tyrosine residues.

These peaks exhibits blue shifts suggesting that residue moved to more polar environment after magnetic field exposure.

b) FTIR Spectra :

Infrared spectroscopy is well established technique for analysis of protein secondary structure. FTIR spectra of BSA protein solution expose to magnetic field of 300 G were obtain in range of (400 to 4000)cm-1 as shown in figure (2 and 3) FTIR spectrum of BSA protein was compared before and after magnetic field exposure.

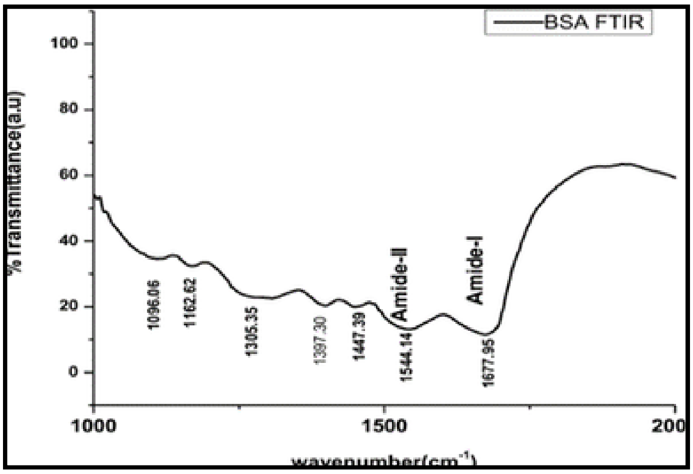

Figure 2: FTIR Spectra of a) BSA Control

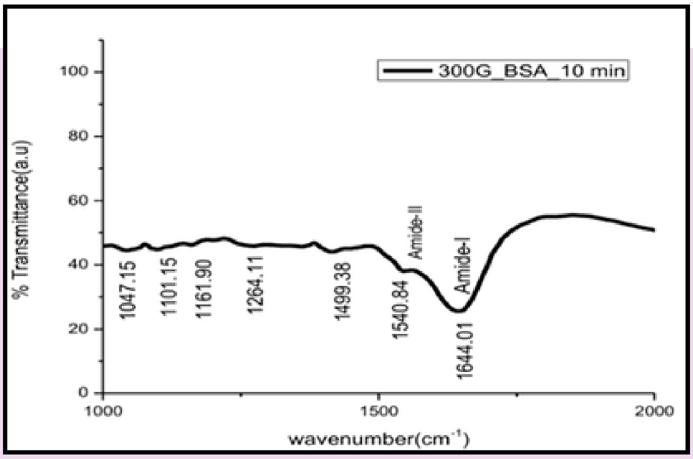

Figure 3: FTIR Spectra of b) BSA expose to magnetic field for 10 min

The FTIR spectrum of without magnetic field shows the peaks at wavenumbers 1677.95 cm^{-1}(C=O stretching), 1544.14 cm^{-1} of (N-H bending and C-N stretching), 1447.39 cm^{-1} (C-H bending), 1397.30 cm^{-1} (N=O symmetric stretching). 1305.35cm^{-1} (C-N stretching), 1165.62 cm^{-1} (C-O bending), 1096.06 cm^{-1} (C-O stretching) with decrease in the percentage transmission. Amide I band (1600-1700) cm^{-1} is the most important band in the FTIR spectrum of secondary structure polypeptides and proteins and is widely used for analysis of secondary structure of proteins.

Table 2: FTIR spectra associated with functional group and corresponded to % transmission

SrNo	Assignment	Wavenumber (cm-1) BSA(control)	Wavenumber (cm-1) BSA 300 G	BSA Control % T	BSA (300G)10min %T
1	Amide –I C=O stretching	1677.95	1644.01	11.65	25.25
2	Amide –II N-H bending C-N stretching	1544.14	1540.84	13.14	38.31
3	C-H bending	1447.39	1499.38	20.01	44.94
4	N=O Symmetric stretching	1397.3	1264.11	20.34	45.99
5	C-N stretching	1305.35	1161.9	22.5	46.28
6	C-O bending	1162.62	1101.15	32.5	44.25
7	C-O stretching	1096.06	1047.15	35.09	44.63

The structural information like fractions of α- helix, β-turn, random coil and β-sheet structure of protein can be derived from the peak positions intensity, width and area in the FTIR spectrum, respectively. With exposure of static magnetic field the transmission increases from 11.65% to 25.25% for Amide I group. Comparing with control and magnetic field samples, the intensity of FTIR spectra of the exposed magnetic field samples increase with magnetic field. Which suggest that the protein molecules are very sensitive to magnetic field and were partly damaged by magnetic field. Since secondary structure are more likely to be damage by the bond breaks Thus they exhibit higher sensitivities to magnetic field exposure. Secondary structure of protein are often highly related to the biological activities of protein usually contain some active hydrophilic groups. This effect suggest that aggregation proceeds of native BSA would proceed through inter-beta sheet formation. Aggregation of BSA leads to different human diseases. The secondary structure modification may lead to functional alteration of protein molecules which may cause mutation or death of organism.

5. Conclusion:

In the present study the effect of magnetic field on Bovine Serum Albumin (BSA) protein is monitored using UV-Visible spectroscopy and FTIR spectroscopy shows difference in control and expose spectrum. The study revealed that the protein was severally affected by static magnetic field exposure for different timing decrease in absorption and increase in transmission were attributed to the damaging effect of magnetic field.

The morphological, structural and functional changes depend on the strength and duration of the magnetic field.

The change in UV spectra of BSA due to Magnetic field exposure are mainly cleavage of bonds of protein structure.

Due to magnetic field exposure transmittance is increase means greatly affected by the local. environment to different structural groups.

6. Challenges and Future Research in Magnetic Field Effects:

Despite extensive studies on the **elementary chemical and biochemical reactions** induced by magnetic field, research at the **macro-system level** remains limited. There is growing interest in exploring how **external magnetic field** influence **aggregation processes** in suspensions of biological macromolecules. **Blood properties** under exposure to magnetic fields. **Protein synthesis** rates and the **structural integrity of proteins.**

Some studies suggest that prolonged exposure to magnetic fields may lead **protein degradation,** potentially affecting tissue function and inducing cellular damage.

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Do You Know ?

Animal GPS?

- Many animals like birds and fish use the Earth's magnetic field as a built-in navigation system — a process still not fully understood but suspected to involve quantum biology.

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Biophysics Behind Controlled Drug Delivery Systems

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In the ever-evolving field of pharmaceuticals, precision is key. Controlled drug delivery systems (CDDS) stand at the forefront of this innovation ensuring that drugs are released at the right time, in the right amount, and at the right site. But what silently governs the mechanics behind this precision? *Biophysics.*

Biophysics is an interdisciplinary science that applies physical principles to understand biological systems at the molecular and cellular levels. In the field of pharmaceuticals, it plays a crucial role in the development of Controlled Drug Delivery Systems (CDDS), which are designed to deliver therapeutic agents with precision in both location and timing while reducing systemic side effects. Biophysical insights help elucidate key parameters such as drug diffusion rates, membrane permeability, and interactions with physiological barriers, factors that are essential for achieving targeted and sustained drug release.

In CDDS, biophysics is fundamental to studying and optimizing the following:

- **Diffusion kinetics:** Governed by Fick's laws, drug movement across a polymer or lipid barrier depends on concentration gradients, molecular weight, and matrix porosity.
- **Thermodynamics:** The Gibbs free energy determines whether a drug remains stable and bioavailable within the carrier until triggered for release.
- **Membrane biophysics:** Understanding the permeability, fluidity, and charge of synthetic and biological membranes is critical for optimizing nanoparticle uptake across epithelial barriers.

Real world example:
Diving into the real world example, a notable application is the intranasal delivery of insulin via Nanostructured Lipid Carriers (NLCs), developed to bypass hepatic first-pass metabolism and offer rapid systemic absorption. Researchers used Differential Scanning Calorimetry (DSC) and Zeta potential measurements to fine-tune the vesicle's bilayer composition, thereby enhancing mucosal adhesion and controlled release. This approach reflects how biophysical tools help in designing patient-centric drug delivery strategies.

Biophysical Tools in Formulation Science:
Biophysical characterization plays a pivotal role in the rational design and development of drug delivery systems. These techniques provide critical molecular-level insights that aid in optimizing formulation performance, enhancing reproducibility, and ensuring product quality. Among the most widely used tools, Differential Scanning Calorimetry (DSC) is employed to assess the thermal behavior of polymers and lipids. It helps determine melting points, crystallinity, and drug-lipid compatibility by analyzing phase transitions. Dynamic Light Scattering (DLS) is another essential technique used to measure particle size distribution and polydispersity index (PDI), which are crucial parameters for evaluating the stability and targeting ability of nanoscale carriers.

Isothermal Titration Calorimetry (ITC) offers a powerful way to quantify the thermodynamics of drug–polymer or ligand–receptor interactions. By evaluating parameters such as binding enthalpy, entropy, and affinity, ITC provides deep insights into formulation efficiency and targeting potential. Likewise, Surface Plasmon Resonance (SPR) enables real-time, label-free monitoring of biomolecular interactions. It is particularly valuable in the development of targeted drug delivery systems, where it helps to characterize the strength and kinetics of drug-ligand binding.

For morphological and surface characterization, techniques such as Atomic Force Microscopy (AFM) and Transmission Electron Microscopy (TEM) are indispensable. These tools reveal nanoscale features, surface roughness, and the architecture of carrier systems. Additionally, structural and chemical bonding analysis is carried out using Fourier Transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD). FTIR helps identify functional groups and confirm encapsulation, while XRD provides insights into the crystallinity and polymorphic state of drugs within carriers.

Altogether, the integration of these biophysical tools not only bridges formulation science with physicochemical principles but also paves the way for the development of advanced, efficient, and intelligent drug delivery systems tailored for specific therapeutic outcomes.

Future Interventions:

Biophysics is poised to significantly transform pharmaceutical sciences by enabling a new generation of intelligent and adaptable therapeutic systems. Advances in artificial intelligence–driven simulations are enhancing molecular dynamics studies, allowing for more accurate drug screening and prediction of release profiles. The development of smart nanocarriers that respond to stimuli such as temperature, pH, redox potential, or light offers controlled and site-specific drug delivery tailored to physiological conditions. Additionally, the integration of organs-on-chip with biophysical sensors is enabling real-time simulation of drug absorption, distribution, and metabolism, closely mimicking human physiology. Emerging research in quantum biology is also opening novel avenues for drug discovery by exploring phenomena like quantum tunnelling and coherence in enzyme–drug interactions. Together, these innovations promise to elevate the precision, personalization, and overall effectiveness of pharmaceutical therapies.

Limitations:

Challenges still persist for the formulation development including the principles of biophysics as ;

- In vitro models may oversimplify complex biological systems.
- High-end biophysical instrumentation demands substantial investment and expertise.
- Interdisciplinary data interpretation is essential but often underdeveloped.
- Scaling from lab to industry while retaining biophysical properties is non-trivial.

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Do You Know ?

The Physics of Precision:

- Biophysics helps determine where and when a drug is released in your body by calculating things like diffusion rates and membrane permeability

LIGHTS, CAMERA, and .... Mr. CHAMELEON: Physics Behind Nature's Intriguing Kaleidoscope

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Human eyes are one of the nature's most complex bio-machines that are part of the brain's neural network that lies outside the brain. Moreover, the resolution of the human eye is estimated to be 576 megapixels and till date it is one of the best cameras in spite of technical advances made by humans. The retina of the eye contains millions of specially designed light-sensitive receptor cells i.e., rods and cones, giving rise to a trichromatic (blue-red-green) colour vision in humans. In spite of all these accolades, humans are technically blind as they are capable of seeing only the colourful wavelengths between 380 nm-720 nm, accounting to a meagre 0.0035% of the entire electromagnetic spectrum, and over the top, some people are even colour blind! In spite of this, colours are an inseparable part of the human experience and existence. Understanding of the vibrant hues of the nature to the carefully chosen shades truly make humans one of a kind in the animal kingdom.

To make this human life colourful, mother nature's magnificence never disappoints. Even though she has designed colourful plants, flowers, animals, skies and other earthly treasures, some remains majestic and almost magical. One of them is none-other-than **Mr. Chameleon**. For instance, the Panther Chameleon (*Furcifer pardalis*), native to Madagascar, is well known for its vibrant colour displays and dynamic skin pattern changes.

Chameleons (family Chamaeleonidae, as shown in Fig. 1) are well-known for their striking ability to change colours, often associated with their camouflage to the surrounding or to the mood-swing they experience. For many years, the cause behind this colour change was supposed to be in the bio-chemical pigmentations on the skin. However, in reality, Mr. Chameleon has mastery over the Physics, that too in Photonics and Nanoscience & Nanotechnology (of course Mr. Chameleon doesn't know it — naturally)! Yes, the secret to a chameleons' colour-changing hues lies in the way they manipulate the light itself which makes them incredibly difficult to see. The reason behind it is equally intriguing. To start with, Mr. Chameleon is utterly and hopelessly defenceless. Most of them are teeny-tiny around 6 inches. They can't bite severely like Gila-monster lizard (*Heloderma suspectum*), their skin isn't packed with poisons like Dart Poison Frog (*Dendrobates auratus*), and they can't move quickly like Brown Basilisk lizard (*Basiliscus vittatus*).

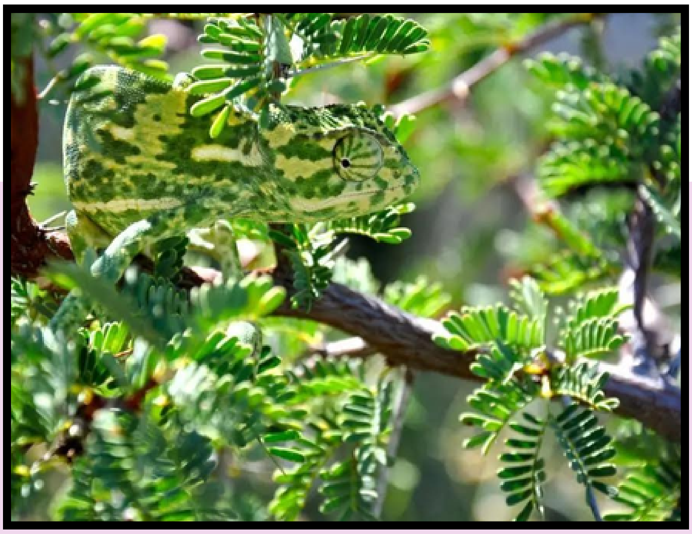

Fig-1: Mr. Chameleon … but where?

Staying hidden with camouflage is pretty much their only tactic to evade predators. They do it quite well in style, and of course, with a lot of colours.

What Really Makes Chameleon the Kaleidoscope of Nature?

Most people assume a chameleon changes colour due to its capacity to transfer colour pigments inside its cells all around its body. While the colour pigments play a significant role in some animals, chameleons rely on a far more elegant mechanism: motion of **NANOCRYSTALS.**

How Do They Do It?

Beneath the outer layer of a chameleon's skin, there lies a layer of **iridophores**, i.e. special cells embedded with guanine photonic nanocrystals of different sizes, shapes and with varying density that are interspersed with the 'regular' skin cells. These nanocrystals can reflect light, and by adjusting the spacing between them (or the inter-nanocrystal distance), the chameleon can manipulate the wavelengths of reflected light according to its surroundings, effectively changing its skin colour so that it remains camouflaged to its vicinity [1].

This phenomenon is known as **structural colouration** [1] and here's where the Physics swoops in:

• Tightly packed crystals reflect **shorter wavelengths** like blue and green while,

• Loosely spaced crystals reflect **longer wavelengths** like orange and red (Fig. 2)

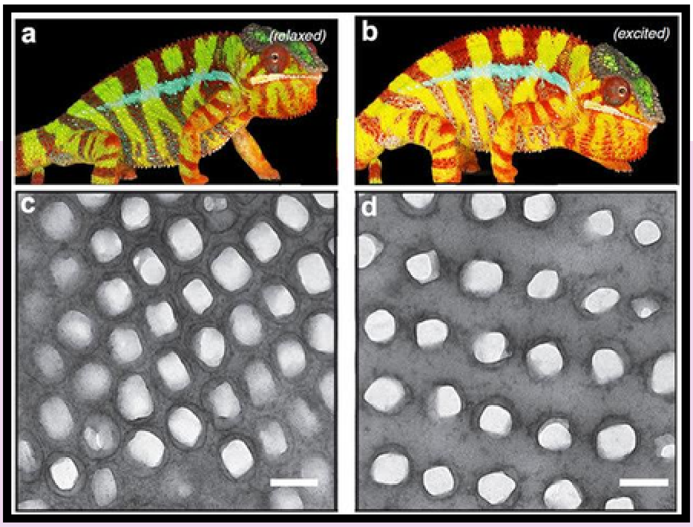

Figure 2: The chameleon in relaxed (a) and excited (b) state and related TEM micro-images (c and d) indicating the relative change in arrangements of the guanine nanocrystals in iridophores, linked to colour change [2].

The fundamentals of this effect can be found in the phenomenon of **constructive and destructive interference of electromagnetic radiations**. By stretching or relaxing their skin chameleons can controllingly alter the spacing between the crystals and thus, their skin colours in real time [1].

Why you need Colour Change Mr Chameleon?

Chameleon's colour change is not just to hide but also to communicate and survive:

1. **Communication:** Signalling to others, dominance and/or submission, readiness to mate.
2. **Mood expression:** Dark colours may signal stress or aggression.
3. **Thermoregulation:** Dark colours absorb heat when they need to warm up; light colours reflect it when they're hot. A chameleon can reduce the heat gain in the extreme high temperature by about 45 % through its skin only [3].

A Natural Masterclass in Nanotechnology:

What makes this even more impressive is that chameleons do all these colourful celebrations without conscious effort or external tools and with a minimum of energy as if it's built into their biology. Yet the principles they exploit are the same as researchers' study in **optics** and **nanotechnology** today. However, we further need to understand how the cognitive and intuitive motor skills of chameleons prompt them to change colours effortlessly as reaction to surrounding.

Inspired Applications:

Scientists are now studying chameleon skin to create adaptive materials: from smart clothing to optical devices. For example, they applied the function of colour change (Fig. 3) for workers' uniforms to visually alarm them in the dangerous zones and hence can save their lives.

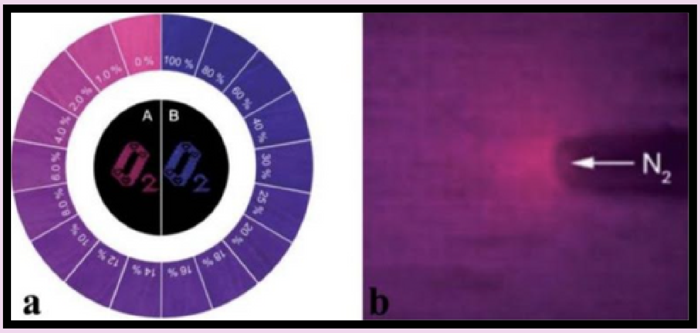

Figure 3: Chameleon-inspired cloth showing colour changes in response to the gas exposure (a) different oxygen concentrations, (b) colour change due to nitrogen exposure in air [4]

Conclusion:

Chameleons are more than just masters of disguise. These remarkable reptiles challenge our understanding of colour and adaptation. As we continue to study such marvels of nature, we gain not only scientific insight but also a deeper appreciation for the correlation of the living world and the physical laws that govern it.

Adios Humans

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Eyes in Space: How Satellite Cameras Changed Our View of Earth?

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Introduction:

Satellite cameras have changed how we observe our planet. These cameras are placed on satellites that orbit Earth and take pictures of land, water and atmosphere. Unlike regular cameras, they are specially designed to survive the harsh conditions of space and capture clear images from far away. This article explains how these cameras work, and how they provide useful information despite obstacles like cloud, sand bad weather. There are many kinds of observation satellites used for various things from military to commercial purposes, but in this article we are going to talk just about the "Earth Observation Satellites"

How Earth Observation Satellite Cameras Work?

Earth observation satellites, such as Landsat and Sentinel, use advanced cameras to take pictures of our planet from space. These satellites often orbit Earth in a path called a sun-synchronous or polar orbit that is perpendicular to the equator, pole to pole, while the earth is moving along its axis. As Earth rotates beneath them, the satellite captures strips of images that are later stitched together to form a complete view.

These cameras work based on a principle called "Ground Sample Distance" or (GSD). GSD is the real-world size of one pixel in the image. For example, if a satellite camera has a resolution of 30 meters per pixel, then one pixel in the image shows a 30x30 meter area on Earth. Satellites like Landsat-8, which flies about 705 km above Earth, can take such high-resolution images. Sentinel-2 flies at a height of around 780 km and offers a similar level of detail.

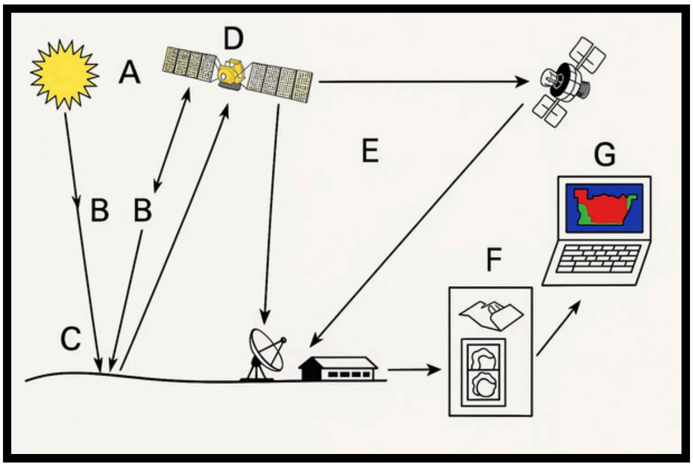
To decide how high the satellite should fly to get the right image detail, scientists use trigonometry. The basic idea is:

$$GSD = (H \times p) / f$$

Where:

- H = Height of satellite
- p = Size of the camera sensor's pixel
- f = Focal length of the lens

This formula helps engineers figure out the best height for a satellite camera to give the needed clarity of images.



How Landsat Creates Images?

The pathway of light used by landsat, from sun to ground, then reflected to landsat, then transmitted to relay stations and sent to computers for analysis.

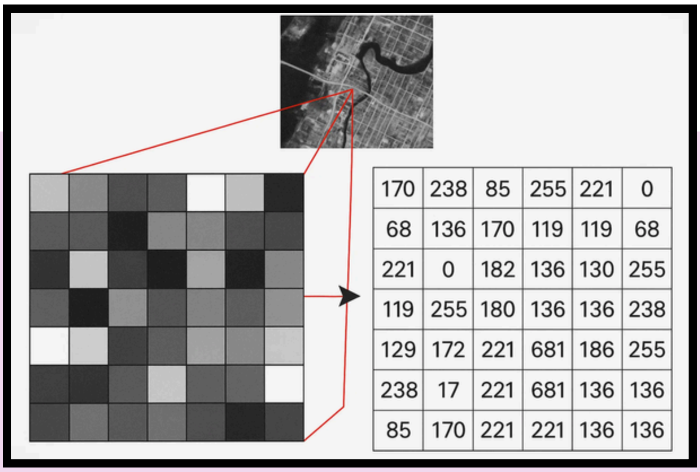
1) All objects with a temperature above absolute zero (-273 degrees Celsius) reflect and emit energy that radiates through space. As sunlight strikes Earth's surface, some of it is absorbed, and some of it is reflected back into space. About 25 percent of the Sun's energy is absorbed by the Atmosphere; about 50 percent is absorbed by the Earth's surface; and about 25 percent is reflected back to space. This 25 percent is the light detected by the sensors of Landsat the "Operational Land Imager" (OLI), it collects data in various spectral bands, including visible, near-infrared, and short-wave infrared.

2) Each location on Earth's lands can be identified by its Landsat path and row, which does not change. Landsat has a spatial resolution of 30 meters. (This means the smallest area on the ground it measures is a 30 m square). Landsat scenes are made up of these 30-meter squares, or pixels.

3) Landsat 7 observes the Earth in 7 ranges (or Bands) of the electromagnetic spectrum.

4) The Landsat instrument records the amount of reflected light in each band for each 30 m pixel, on a scale of 0 to 255. A numerical value of 0 represents no reflected light and a numerical value of 255 represents maximum reflected light.

5) We have to assign colors to represent Landsat bands (using computer software). Landsat uses some bands of infrared light, and the human eye is not sensitive to Infrared. So to build an image we can see that includes data about infrared light gathered by Landsat, we must represent that data with colors, we can see: red, green, and blue. People can chose red, green, or blue to represent any of the wavelength ranges they like. We see more than we could otherwise.



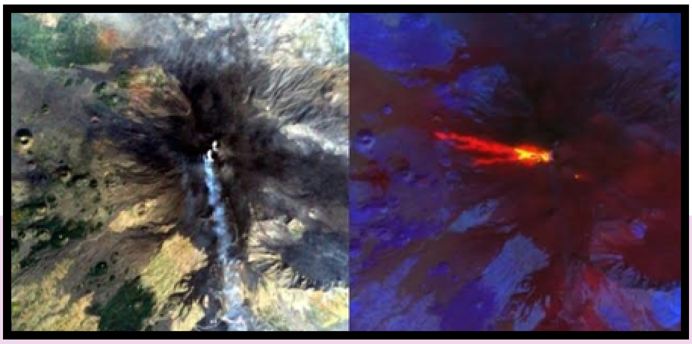
Dealing with Clouds and Weather?

Clouds and bad weather make it hard to get clear images using regular cameras. To overcome this, some satellites use radar or sonar-like technology called "Synthetic Aperture Radar" (SAR). Instead of light, these satellites send out radio waves that bounce off the surface and return to the satellite. This helps create images even at night or through clouds. These images are usually black and white and may look noisy, but they are extremely useful for studying terrain, floods, and even tracking changes in forests.

SAR systems, such as those used by ICEYE and Capella Space, can operate day or night and in all weather conditions, providing consistent and reliable imagery. These systems are invaluable for applications like flood monitoring, where timely data is critical regardless of weather conditions.

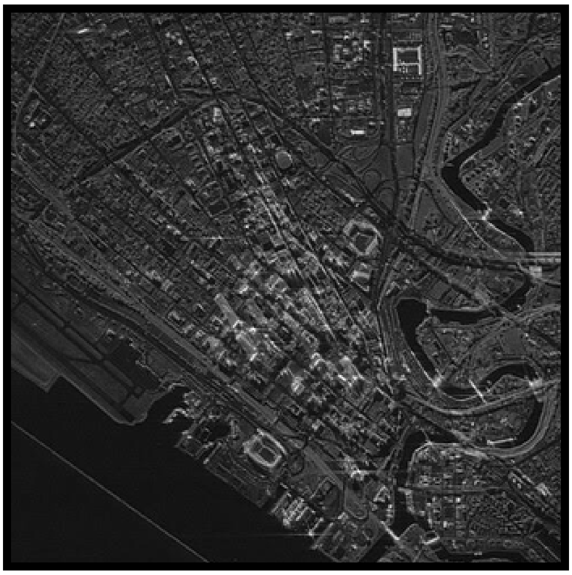
Difference between Satellite Cameras and Normal Cameras:

- Normal Cameras (like DSLRs or smartphone cameras):
- These cameras work by letting light enter through a lens onto a sensor.
- The lens focuses light, and the sensor captures the image.
- The distance between the camera and the object is usually small.
- They work best in good lighting conditions.



Earth Observation Satellite Cameras:

- These cameras orbit the Earth and take images from hundreds of kilometers above.
- They use special sensors that can capture images even in different light wavelengths (not just visible light).
- The resolution depends on their height and sensor type. Using trigonometry, scientists calculate how much of the ground (like 30m x 30m) one pixel of the image represents.
- They take images in long stripesand combine them to form large maps.
- If there are clouds, some satellites use radar (like sonar in space) to "see" the Earth's surface by sending radio waves.
- Deep Space Satellite Cameras:
- These cameras are like advanced telescopes.
- They are built to work in extremely dark and cold environments.
- They need to detect very faint light from distant stars and galaxies.
- They are also made to last many years without human repair.
- Cameras like the one on the James Webb Telescope use infrared sensors to see things invisible to normal cameras.



Notable Earth Observation Missions:

Landsat Series: Started in 1972,the Landsat satellites have been providing valuable data for agriculture, forestry, water management, and urban planning.

Sentinel Series(ESA): These satellites are part of the Copernicus program and provide free Earth observation data. Sentinel-2, for example, gives high-resolution optical images used for vegetation, soil, and water monitoring.

ICEYE: A Finnish company operating a constellation of SAR satellites, ICEYE provides near real-time imaging capabilities, crucial for monitoring natural disasters and supporting defence operations.

Capella Space: An American company specializing in high-resolution SAR imagery, Capella Space's satellites offer detailed Earth observation data, aiding in applications like infrastructure monitoring and environmental assessment.

RISAT Series: India's RISAT (Radar Imaging Satellite) series, developed by ISRO, is designed for all-weather, day-and-night Earth observation using Synthetic Aperture Radar (SAR). These satellites operate in sun-synchronous orbits around 555 km high and can capture images through clouds and darkness making them ideal for disaster management, agriculture monitoring, and military surveillance.

Conclusion:

A simple camera on a satellite has transformed our understanding of the world. From predicting the weather and studying climate change to improving GPS navigation and monitoring disasters satellite cameras have become essential tools. Even in warfare, they offer intelligence without risking human lives. In deep space too, advanced imaging systems allowed us to take actual pictures of black holes, turning mathematical predictions into visual reality.

These technologies prove that something as basic as a camera, when placed in space, can unlock the secrets of our world and beyond.

Quantum Reality and the Illusion of Existence: A Scientific and Philosophical Synthesis

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"*The distinction between past, present, and future is only a stubbornly persistent illusion.*" — Albert Einstein

Introduction: A Convergence of Physics and Metaphysics

Quantum mechanics has revealed a universe far more intricate and paradoxical than classical physics ever imagined. The traditional categories of "particle" and "wave" no longer hold absolute meaning. Instead, quantum entities exist as wave functions, mathematical constructs that contain the superposition of all possible states. Only upon measurement does this wave function collapse into a definite outcome—an act inherently linked to the observer's participation.

This scientific insight finds profound resonance in Indian metaphysics, especially in the concept of Māyā —not merely illusion, but the very principle of measurement, differentiation, and manifestation. Drawing upon the Vedantic and Sāṃkhya traditions, this essay explores how Māyā and quantum theory can be synthesized into a unified understanding of reality as appearance.

Wave Function and Measurement: The Role of the Observer

In quantum mechanics, a system does not possess definite properties until observed. Until then, it exists in superposition, a mathematical sum of all possible states. This is exemplified by the double-slit experiment, where particles such as electrons behave like waves when unobserved but like particles when observed.

This ties to the philosophical insight that reality is not independently existent, but rather comes into being through perception:

दृष्टिप्रश्न क्रिया भयादय: काल:

Dṛṣṭi praśna kriyā bhayādayaḥ kālaḥ

"Time arises through perception, inquiry, action, and fear."

This śloka suggests that time a central axis of our reality is a construct of consciousness, not an independent, objective dimension. It reflects the observer-centric nature of quantum time, where the arrow of time emerges only upon interaction.

Māyā: The Power of Measurement and Manifestation

The term Māyā originates from the Sanskrit root "ma", meaning to measure. Contrary to its simplistic translation as "illusion," Māyā is better understood as the power by which the formless becomes form, through differentiation and measurement.

इन्द्रमायाभिः पुरुरूप ईयते

Indra māyābhiḥ pururūpa īyate

"Through his own Māyā (measuring power), Indra manifests in manifold forms."

Here, Indra represents the cosmic agent or observer, whose measuring capacity brings forth multiplicity from unity an exact analog to the observer effect in quantum physics.

मायाभिःबहुरूपी

Mayābhiḥ bahurūpī

"Through Māyā, the One appears as many."

बिम्ब-प्रतिबिम्ब

Bimba–Pratibimba

"The reflected image and its source."

The Bimba-Pratibimba doctrine expresses the metaphysical idea that the observed universe is a projection or reflection of an ultimate, unmeasurable reality. Similarly, in quantum physics, the reality we observe is not fundamental it arises post-measurement, like a reflection of a deeper quantum potential.

Three Levels of Reality: Indian Schools of thought, Phylosophy and Physics

Indian School of thought delineates three levels of reality that mirror the stratified perception of reality in quantum mechanics:

Vyavahārika Satya (Empirical Reality)

The observable, classical world. Governed by cause and effect, it corresponds to measured quantum outcomes.

Prātibhāsika Satya (Projected/Illusory Reality)

Cognitive constructs, illusions, and misperceptions. Analogous to quantum superposition, where multiple states exist before observation.

Pāramārthika Satya (Transcendental Reality)

The ultimate, undivided reality beyond space-time. Similar to the quantum vacuum or unified field an all-encompassing potential beyond form.

These realities are not in conflict they are hierarchical, with Māyā serving as the bridge between them.

Time, Motion, and Space: Constructed by Consciousness

Classical physics treats time and space as fundamental dimensions. Quantum physics and Vedantic thought challenge this.

कालात्क्रिया विभ्रान्ते आकाशः

Kālāt kriyā vibhrānte ākāśaḥ

"From time and action, space arises."

This śloka suggests space is not a backdrop, but arises through the interaction of time and motion concepts which are themselves functions of perception.

आदित्यग्रह नक्षत्र सिन्न भिदेन कालोत्तरः

Āditya graha nakṣatra sin bhidena kālottaraḥ

"Time emerges from the varying movements of celestial bodies the sun, planets, and stars."

Attributed to Sage Bhartṛhari, this śloka remarkably anticipates celestial mechanics and relativistic concepts of time. It proposes that cosmic vibration and orbital spin generate our sense of time a view compatible with astrophysical time dilation.

Mathematics: The Structure of Māyā

Mathematics especially calculus, algebra, and differential geometry becomes the language of Māyā, enabling us to model the dynamics of reality.

Differential equations express the change inherent in quantum systems.

Integrals unify fragmentary data into holistic expressions mirroring the transition from measured reality to the unmeasured whole.

Complex numbers, though imaginary, describe real quantum behaviors further blurring the line between reality and illusion.

Māyā is not falsehood. It is structured illusion a system that renders the infinite finite, the unmeasured measurable, and conscious potential into form.

Conclusion:

The Science of Appearance Quantum mechanics and Indian metaphysics converge on a profound truth: Reality is observer-dependent, and what we perceive is not the thing-in-itself, but a projected reflection shaped by consciousness.

As Sri Aurobindo wrote in his Upanishads (Vol. 12):

"Yet are they both facts Identity is a fact in the reality of things, difference is a fact in the appearance of things. The world of phenomena is, in its essence, nothing but seeming and difference."

Māyā is not a denial of reality, but a recognition of its layered nature. In the quantum universe, as in Vedantic insight, the act of knowing creates the known. The illusion lies not in the form, but in mistaking it for the whole.

Final Reflection

Māyā is:

A principle of measurement, not a substance;

A process of manifestation, not deception;

A bridge between empirical multiplicity and transcendental unity.

Quantum physics, in its pursuit of fundamental truth, appears to circle back to ancient insights: Existence, as we perceive it, may not be ultimately real—only deeply, convincingly structured by the measuring power of consciousness.

Reality might not be true—just deeply convincing.

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A Space-Time-Motion Approach in Understanding the Influence of Clockwise and Anticlockwise Rotation in our Life

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The concept of rotations does not require any reference as it is accepted by all the fields such as Physics, Mathematics, Yoga, Ayurveda, etc. In stereochemistry we come across the terms laevorotatory and dextrorotatory. It is a Multidisciplinary Concept. Pradakshina in Indian tradition is an integral aspect. It also forms a part of religious act. Circular rotations are not only important but scientifically more complex because rotations in itself is centrifugal force and it induces artificial (pseudo) gravity. The rotations cause Coriolis forces since body contains liquids. Rotations cause impacts on Vibrational force, Tidal force, buoyant force, convective currents, tensile forces, osmotic forces etc on the body and its physiology.

Effects on Human Body:

Clockwise rotations induce more warmth while counterclockwise rotations reduce warmth. It affects all the physiological systems. Another impact of rotatory motion is that even after the rounds are over the effect persists for a long time. It symbolizes cyclic patterns when subject to repetition, is prove to affect positively all the activities in the body and re-establish the lost cyclicity of any system. When any parts of body like head, eyes, the hands, the feet etc are rotated those parts are affected locally. On the other hand, obese and thin are by nature associated with anticlockwise and clockwise respectively so therefore opposite pattern is medicine for them. The understanding of the distinct effects of these rotations emphasizes their importance as a technique for treatment and manipulation. The clockwise rotation has been identified as an antidote for obesity. Therefore, it is prescribed for obese people suffering from hypertension.

It should be noted that the heart itself automatically has proneness to the clockwise rotatory pattern, that is clear from vertical position.

The natural movement of heart tends to have the clockwise motion within the limit. The effects of clockwise rotations have an impact also on neuro-sensory, the psycho-cognitive level and that has in turn a positive influence on the neuro centre and neuromotor system. On the higher level, mental tension is also released. The intra-cerebral pressure, ocular pressure also seems to have positive impact. The effects of reverse clockwise rotation are in the same line but has more accelerated impact than the ordinary clockwise pattern. Reverse clockwise rotation needs more systematic coordination of psychosomatic profile and naturally has an additional and sustainable effect on the blood pressure.

Thin people generally suffer from hypotension. The rotatory pattern for thin people is opposite to that of the obese people, i.e. counterclockwise one. Therefore, impact and effect of it is opposite to those of the clockwise pattern. Positive impact on respiration, neurosensory, psycho-cognitive level is observed. Stability in perception, mental strength is positively affected.

Effects on Food:

The dough of wheat flour for making puris of 1st group was first rotated anticlockwise and in the same fashion after putting them on heating oil. Other group was taken in which the dough was rotated clockwise and in same fashion rotated in heating oil.

The 1st group had concave pattern, it absorbed more oil and did not look fresh.
The 2nd group was opposite in appearance, it had convex pattern, it absorbed marginal oil, and was looking fresh and crisp.

The pattern of grinding (clockwise) on vertical or horizontal plane are seen in grinding machines. The motion in the mixer or the grinding stone or to and fro pattern (done by hands), do have a graded impact.

It is stated that *idlis* subject to subject to clockwise grinding are softer than anticlockwise grinding. Nowadays we get only clockwise grinding machines in the market due to this.

While extracting oil, preparing hair oil, creams etc. only one type of motion i.e. clockwise is used in laboratories, industries and factories. Scientifically this is only one type of motion, as compared to its opposite type i.e. anticlockwise. This is still an unexplored field, effects of these two types could be the applied topic in Life Sciences.

Effect on Plants:

The jute seeds were kept for budding in the transparent half cut plastic bottles filled with water. The two platforms rotating clockwise and anticlockwise patterns were used. They were running parallel but opposite to each other with constant biological speed of 15 rpm for 24 hrs. A stationary platform was used as a reference point, they were kept inside the room but not directly exposed to the sun. The experiment was started on the first lunar day of the beginning of the new year after Diwali continued for a month to cover both the fortnights.

Observations:

1.The germination in the rotating platforms was quick and pronounced as compared to static one.

2.The root of the budding had an upward loop before it went straight down.

3.The growth of the plant from the clockwise platform was little more than that of the other.

4.The colour of the plant from the clockwise platform was more reddish than that of the other.

5.The height of the plant from the clockwise platform was more but the width was less as compared to the counterclockwise platform.

6.The leaves of the plant from clockwise platform were pointed while those from other were less so.

Conclusions:

- Clockwise and Anti Clockwise rotations are mutually opposite phenomena so their **effects are also opposite.**
- Clockwise rotations induce **centrifugal force**, they are outgoing, move away from the centre, exothermic in nature, exploding, negative (physics) and destructive.
- Anticlockwise rotations induce **centripetal force**, moves towards the centre, incoming, endothermic in nature, imploding, positive(physics) and nourishing.
- In order to grasp the profoundness of rotations and their effects, it is crucial to recognize that objects or bodies are not homogenous masses but rather have an uneven distribution on both horizontal and vertical axes. It is true mathematically by using **Symmetry Asymmetry**.

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Black Hole

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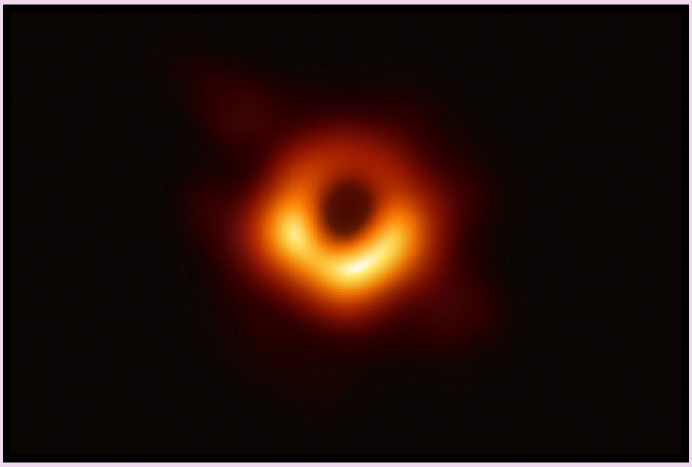
Black Holes remained largely unknown until the 20th century. A black hole is a region in space where the force of gravity is so strong not even light can escape. "From the outside, you cannot tell what is inside a black hole." Black Holes haunt our universe dark centers of gravity.

How are Black Holes formed ?

Black holes are formed by stars, so there some material at its center. But in the stars, even our sun is a star, there is a continuous nuclear fusion reaction at their center. These reaction produce continuous heat and light. The heat being produced sends a force outwards and at the center of the star, there is the force of gravity this helps the star remain intact and alive. This is how the stars maintain equilibrium throughout their lives, the forces pushing outwards due to the reaction. And the forces pulling inwards due to gravity. But there reactions takes place a fuel exists. Either Hydrogen or Helium.



The first photo of a Black Hole

The fuel wouldn't always be there. It would get burned up at same point and when the fuel ends, there would not be any forces pushing outwards and the gravitational force pulling inwards would not be countered by an equal force, so that star will collapse on itself because of its own gravity. This will take a long time, by the way. Our Sun expectancy is around 10 billion years. But what happens next depends on the mass of the star. The black hole is not like a big black ball that sucks everything around it.

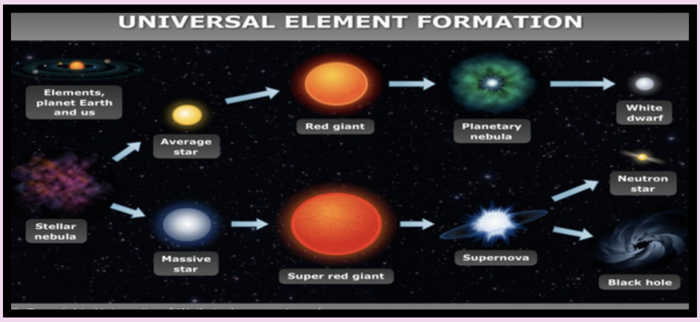
Einstein Theory of Relativity

Let begin with the beginning of this story, The history of black holes is not very long. 100 years ago, no one knew about black holes, Because of Einstein Theory of Relativity, black holes were later discovered, there are two parts of theory, The special theory of relativity published by Einstein in 1905 and The general theory of relativity. The special theory of relativity tell us how Speed influences time. Aqua Planet one hour on that planet Equals seven years on earth. This happens on the planet because the planet was very close to the Gargantua black hole, so the gravitational force of the black hole impacted the time.

If you are in a spaceship that is going very fast, if the speed is too high, time will slow down you. Relative to the people not on the spaceship, black on earth the word relative is very important because when you are in a spaceship you would not feel the time slowing down. You would think that time is flowing at the same speed as it normally does. But when you will get back to the earth, you will find out that there was a difference in the flow of time. This known as Kinematic time Dilation, not only speed but even gravity can also result in time dilation as Einstein in his General Theory of Relativity. This was developed by him in 1915. The more gravitational force you do experience the more time would slow down for you. This is known as gravitational time dilation. Einstein wants us to imagine a space-time fabric, kind of like a mesh, on which all planetary objects are placed. The space-time fabric bends due to the mass of the objects and when the mesh bends, not only does not attract physical objects more, but it leads to time dilation as well, and the other forms of energy, such as sound, heat or light they are affected by gravitation as well. Universe which have such a high Gravitational force that they can completely absorbed light. If there are such objects, it means that they do be completely black. We would not be able to see them. Because not even light can escape them this is exactly what black holes are. When Einstein presented his theory of General Relativity the concept of black holes was merely theoretical back the Einstein knew that gravitation influences light and Theoretically,, objects that can absorb light were possible.

Light speed limits gravity influence. We don feel gravity force instantly, everywhere it upper limit is the speed of light. Suppose that the Sun disappeared suddenly, as we know, we will get to know this eight minutes later, On earth, because it takes eight minutes for sunlight to reach earth. But, According to Einstein, The Gravitational impact of the Sun disappearance, will also be left eight minute later.

Life Cycle of a Star



Let look at the picture of the life cycle of a star. If the mass of the Star is not high, i.e., If I was a small, or average-sized star, it turns into a Red Giant. After which it can become a planetary nebula, or a white Dwarf. But if it was a hugestar, a star will a lot of a mass, when it runs out of fuel it cools down and turns into a Red super Giant. And then the super Giant bursts and turns into a super Nova. After this, a tiny core remains. In the core is tiny, it is called a Neutron Star, But anything bigger than that, we call it a Black hole. The mass of the star after it collapse due to its gravitational force, it becomes small and condensed, it can turn into a black hole.

How small is the volume of the compressed star ?
For a star as big as our sun, if that turns into a black hole, the diameter of that black hole will be merely 50km.

There are mainly 3 Types of Black Holes

Stellar Black Holes : That is the most common type of black hole. The black holes that were created by stars, Scientists estimate that in our Milky Way Galaxy, there are anywhere between 10 Million to 1 Billion such Black holes.

Primordial Black Holes : It an assumption that These black holes are small as an atom. But their mass is like that of a mountain. These black holes are merely Theoretical, Hypothetical.

Supermassive Black Holes : These black holes are enormous. So big that their mass is more than that of 1 Million Suns combined. And it fits into a ball whose diameter is as big that our Solar system. The Supermassive Black Hole at the center of our Milky way Galaxy is called Sagittarius A.

What if you fall inside a Black Hole?

There are some interesting theories that are suggested. Like we cannot see inside a black hole from the outside, because the light is absorbed into it, One theory says that inside of event horizon, light reflects off at multiple points before reaching singularity. So it is possible that inside the event Horizon, things would actually be visible. One thing is sure here, if you fall into a black hole, the chances are that you will disintegrate into pieces due to the gravitational Force. You will die in milliseconds.

Conclusion
"Gravitation affects almost everything. Not only are Physical Objects attracted by the force of gravitation. It attracts heat, sound and light as well." There is no need to be scared of black holes. Earlier, many people had this misconception that the black holes suck up all matter, keep getting bigger and eventually, it will end the whole universe but that not how it works.

Do You Know ?

Ground Sample Distance:
- Satellite camera clarity is measured by something called Ground Sample Distance (GSD) — it tells you how much real-world area one pixel in the image covers!

Size Compression
- If our Sun turned into a black hole, its size would shrink to just 50 km in diameter. Imagine compressing a massive object like the Sun into something the size of a small city

Chameleons don't change color using pigments.
- They use photonic nanocrystals embedded in special skin cells called iridophores to reflect different wavelengths of light.

बिभा चौधरी : नोबेल पारितोषिकाने हुलकावणी दिलेली भारतीय महिला वैज्ञानिक

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हि गोष्ट आहे तब्बल ११२ वर्षांपूर्वीची. हिंदुस्तानात ब्रिटिशांचे राज्य होते. बहुतांशी जनता ब्रिटिशांच्या विरोधात स्वातंत्र्ययुद्ध लढ्यात सामील होत होती. ब्रिटिशांच्या राजवटीत १९१३ मध्ये भारतीयांच्या दृष्टीने एक अभिमानाची गोष्ट झाली ती म्हणजे भारताचे पहिले-वहिले नोबेल पारितोषिक सुप्रसिद्ध बंगाली लेखक, कवी, संगीतकार रवींद्रनाथ टागोर यांना मिळाले होते. या काळात शिक्षण सर्वांसाठी उपलब्ध नव्हते, महिलांना तर नाहीच नाही. अश्या काळात बिभा चौधरी यांचा जन्म एका बंगाली सुशिक्षित कुटुंबात कोलकाता येथे झाला. बिभाचे वडील बंकू बिहारी चौधरी डॉक्टर होते तर आई उर्मिला देवी ब्राम्हो समाजाच्या अनुयायी होत्या. ब्राम्होसमाज हा ब्राम्हो धर्माचा सामाजिक घटक आहे, जो पश्चिम बंगालच्या पुनर्जागरण काळात एकेश्वरवादी सुधारणावादी चळवळ म्हणून सुरू झाला. या ब्राम्होसमाजाच्या शिकवणी नुसार प्रत्येक मुलीला शिक्षणापासून वंचित न ठेवता मुख्य प्रवाहात सामील करण्याचा आग्रह होता. पालक सुशिक्षित असल्यामुळे बिभा यांना कुठल्याही शिक्षणाची अडचण आली नाही. अडचण भासली ती फक्त स्त्री-शिक्षण द्वेष करणाऱ्यांची, त्यांच्या संकुचित मनोवृत्तीची. अश्या प्रतिकूल परिस्थितीत बिभा यांनी कलकत्ता विद्यापीठाच्या राजाबझार सायन्स कॉलेजमधून भौतिकशास्त्र विषयात पदवयुत्तर (M.Sc Physics) शिक्षण पूर्ण केले. हे शिक्षण घेत असताना त्या २४ मुलांच्या वर्गात एकमेव विद्यार्थिनी होत्या. त्यांनी भौतिकशास्त्र विषयात संशोधन करण्याचा निर्णय घेतला जो की इतका सोपा नव्हता. कलकत्ता विद्यापीठातील विख्यात शास्त्रज्ञ देबेन्द्र मोहन बोस (पलीत प्रोफेसर डी. एम. बोस) यांच्याकडे बिभा यांनी संशोधन करण्याचा मानस व्यक्त केला. 'महिलांनी संशोधन करण्यासारखे माझ्याकडे कुठलेही विषय नाही' अशी कारणे सांगून बिभा यांना नाकारले. ही घटना सी.व्ही. रमन यांनी बंगळुरू येथील इंडियन इन्स्टिट्यूट ऑफ सायन्समध्ये कमला सोहोनी यांना संशोधन अभ्यासक म्हणून स्वीकारण्यास नकार दिल्याची आठवण करून देते. महिलांच्या क्षमतेबाबत त्या काळातील लोकांच्या मानसिकतेचा विचार करता हे तितके साधे सरळ नव्हते. परंतु बिभा त्यांचा पाठपुरावा करत राहिल्या आणि प्रा. डी. एम. बोस यांना राजी केले.

प्रा. डी. एम. बोस हे त्या काळातील एक महान भौतिकशास्त्रज्ञ होते जे सी.टी.आर. विल्सन यांच्यासोबत 'वातारण कक्ष' (Cloud Chamber) बांधण्यात सहभागी होते आणि पाण्याच्या

वाफेने भरलेल्या काचेच्या निर्वात पोकळीत प्रकाशमान झालेल्या प्लॅटिनम वायरवर (Water Vapour filled Platinum Wire Bulb) तयार होणाऱ्या घनरूप केंद्रकांच्या स्वरूपाचा अभ्यास करत होते. भारतात परतल्यावर त्यांनी कलकत्ता विद्यापीठात स्वदेशी पद्धतीने वातारण कक्ष बांधले. जरी ए. एच. कॉम्प्टन हे वैश्विक किरणांवर (Comic Rays) प्रयोग सुरू करणारे पहिले व्यक्ती होते, तरी भारतातील वैश्विक किरण संशोधनाची सुरुवात कलकत्ता येथे झाली आणि 'पहिले भारतीय वैश्विक किरण भौतिकशास्त्रज्ञ' निश्चितच डी.एम. बोस आहेत.

अल्पावधीत बिभा यांची चिकित्सक वृत्ती आणि संशोधनाबद्दल असलेला प्रामाणिकपणा पाहून प्रा. डी. एम. बोस प्रभावित झाले आणि त्यांना त्यांच्या प्रयोगशाळेत काम करण्यास मुभा देण्यात आली. पूर्ण वेळ संशोधन करत असताना एकाच वर्षात बिभा चौधरी यांचा पहिला संशोधन पेपर "Studies in nuclear disintegration by the photographic plate method-I, Disintegration of samarium nucleus by cosmic rays" या विषयावर होता जो Transactions of Bose Research Institute मध्ये प्रकाशित झाला आणि लगोलग त्याचवर्षी 'नेचर' मासिकात (ज्याचा इम्पॅक्ट फॅक्टर सध्या ६९.५४० आहे) त्यांचा दुसरा संशोधन पेपर प्रकाशित झाला. १९३८ मध्ये नेपाळमधील संदकफू येथे १२००० फूट उंचीवर फोटोग्राफिक प्लेट्स वैश्विक किरणांच्या संपर्कात आल्यानंतर तयार झालेल्या ट्रॅकचा अभ्यास केला. क्लाउड चेंबरच्या विरोधात फोटोग्राफिक प्लेट वापरण्याचा वेगळा फायदा या संशोधनात शिक्कामोर्तब झाला. बोस इन्स्टिट्यूटमध्ये फोटोग्राफिक प्लेट्स वापरून अतिउच्च ऊर्जेच्या वैश्विक किरणांच्या अभ्यासाची ही सुरुवात होती.

त्यानंतर लगेचच बिभा चौधरी यांनी संपूर्ण गांभीर्याने त्यांचा वैश्विक किरणांचा शोध सुरू केला. मेसोट्रॉन वर्षावांचा अभ्यास करण्यासाठी त्यांनी दार्जिलिंग (७००० फूट), संदकफु (१२००० फूट) आणि फारिजोंग (१४००० फूट) येथे तीन वेगवेगळ्या उंचीवर 'Ilford R2' आणि 'New Halftone 2' फोटोग्राफिक प्लेट्स वापरण्यास सुरुवात केली. १९३५ मध्येच युकावा (नोबेल पारितोषिक विजेते Hideki Yukawa) यांनी सैद्धांतिकदृष्ट्या मेसोट्रॉनच्या अस्तित्वाचा अंदाज लावला होता, जे अणूच्या केंद्रामध्ये प्रोटॉन आणि न्यूट्रॉन मर्यादित करण्यासाठी कारणीभूत असलेल्या मजबूत परस्परसंवादाचे मध्यस्थ मानले जात होते आणि मेसोट्रॉनच्या अस्तित्वाची प्रायोगिक पुष्टी ही त्या काळातील प्रमुख संशोधनांपैकी एक होती. फोटोग्राफिक प्लेट्स थेट वैश्विक किरणांच्या (हवेच्या) संपर्कात आल्या होत्या तर काही प्लेट्स पाण्याखाली आणि पॅराफिन मध्ये अभ्यासण्यात आल्या होत्या. या प्रायोगिक तपासांवर आधारित, मेसोट्रॉनचे वस्तुमान मोजणारी बिभा चौधरी या पहिल्या व्यक्ती होत्या. १९४० ते १९४२ या कालावधीमध्ये बिभा यांनी प्रा. डी. एम. बोस यांच्यासह चार संशोधन निबंध 'नेचर' मध्ये प्रकाशित केले. प्रा. डी.एम. बोस आणि बिभा चौधरी यांना या विषयावरील पुढील संशोधनासाठी सुधारित छायाचित्रण प्लेट्सची आवश्यकता जाणवली, परंतु दुसऱ्या महायुद्धादरम्यान लादलेल्या निर्बंधांमुळे छायाचित्रण प्लेट्स उपलब्ध नसल्याने त्यांना हे संशोधन थांबवावे लागले आणि बोस इन्स्टिट्यूटमधील वैश्विक-किरण संशोधनाचा हा शेवट होता. जवळजवळ एक दशकानंतर १९५० मध्ये, सी.एफ. पॉवेल यांना बिभा चौधरी यांनी वापरलेल्या पद्धतीचा (आणि त्यांनी सुचवलेल्या सुधारित प्लेट्सचा) वापर करून अणु प्रक्रियांचा अभ्यास करण्याच्या छायाचित्रण पद्धतीचा विकास आणि मेसॉनशी संबंधित त्यांच्या शोधांसाठी नोबेल पारितोषिक मिळाले. त्या वेळी सुधारित फोटोग्राफिक प्लेट्स उपलब्ध झाल्या असत्या तर बिभा चौधरी या भारताच्या तिसऱ्या (दुसरे नोबेल भारताला डॉ सी व्ही रामन याच्या स्वरूपात मिळाले) व पहिल्या नोबेल पारितोषिक विजेत्या महिला भारतीय झाल्या असत्या.

बिभा चौधरी १९४५ मध्ये पीएच.डी.च्या पुढील कामासाठी नोबेल पारितोषिक विजेते पी. एम. एस. ब्लॅकेट (ब्लॅकेट यांना १९४९ मध्ये 'किरणोत्सर्गीतेमुळे एका रासायनिक घटकाचे दुसऱ्या रासायनिक घटकात अणु रूपांतर' या संशोधनाबद्दल नोबेल पारितोषिक देण्यात आले होते) यांच्या मँचेस्टर विद्यापीठाच्या कॉस्मिक-रे प्रयोगशाळेत सामील झाल्या आणि १९४९ च्या सुरवातीला त्यांच्या अथक परिश्रमांनंतर 'Extensive Air Showers Associated with Penetrating Particles' या विषयावर त्यांना पीएच.डी. पदवी प्राप्त झाली. 'मँचेस्टर हेराल्ड' दैनिक वर्तमान पत्रात 'Meet India's New Woman Scientist - She has an eye for cosmic rays' अश्या मथळ्याची बातमी छापून आली होती, की जी त्यांच्या मुलाखतीनंतर प्रसिद्ध झाली.

पीएच.डी. चे काम पूर्ण केल्यानंतर, बिभाने पॅरिसमध्ये प्रोफे. लुईस लेप्रिन्स-रिंगुएट यांच्या प्रयोगशाळेत काही काळ घालवण्याचा निर्णय घेतला. ही प्रयोगशाळा फोटोग्राफिक इमल्शन तंत्रासाठी प्रसिद्ध होती - एक असे क्षेत्र ज्यामध्ये बिभा यांनी त्यांच्या वैज्ञानिक कारकिर्दीच्या सुरुवातीलाच प्रभुत्व मिळवले होते.

पॅरिसमधील त्यांच्या थोड्या काळाच्या वास्तव्यानंतर, बिभा चौधरी यांनी भारतात परतण्याचा निर्णय घेतला. १९४९ मध्ये पी.एम.एस. ब्लॅकेट यांच्याकडून मिळालेल्या शिफारशीच्या आधारे आणि त्यानंतर एच.जे. टेलर यांनी घेतलेल्या मुलाखतीच्या आधारे त्यांची टीआयएफआर मध्ये नियुक्ती झाली. त्या १ नोव्हेंबर १९४९ रोजी संस्थेत रुजू झाल्या आणि टीआयएफआर मध्ये रुजू होणाऱ्या पहिल्या महिला शास्त्रज्ञ होण्याचा मान त्यांना मिळाला.

टीआयएफआर मध्ये पाच वर्ष काम केल्यानंतर बिभा चौधरी यांनी अणुऊर्जा आयोगाच्या प्रायोजकत्वाखालील शिबपूर (हावडा) येथील बंगाल अभियांत्रिकी महाविद्यालयात एका वैश्विक-किरण प्रकल्पात वरिष्ठ संशोधन फेलो पदासाठी रुजू झाल्या ज्याला डॉ. होमी भाभा यांनी बिभा यांची शिफारस केली होती. या महाविद्यालयात काही काळ काम केल्यानंतर त्यांनी फिजिक्स रिसर्च लॅबोरेटरी, अहमदाबाद येथे कोलार गोल्ड माईन्स (केजीएफ) मधील प्रयोगांवर संशोधन करण्यासाठी रुजू झाल्या. हा प्रयोग केजीएफ येथे ७०० फूट खोलीवर जमिनीखाली ठेवलेल्या डिटेक्टरसह केला जाणार होता आणि जमिनीवर असलेल्या टीआयएफआरच्या एक्सटेन्सिव्ह एअर शॉवर ॲरेसह चालवला गेला.

बिभा यांच्या प्रकाशनांच्या यादीतून हे लक्षात घेणे रंजक आहे की बोस इन्स्टिट्यूट आणि मँचेस्टरमध्ये काम करत असताना त्या आंतरराष्ट्रीय जर्नल्समध्ये शोधनिबंध प्रकाशित करत होत्या, परंतु भारतात परतल्यानंतर त्यांनी त्यांचे सर्व काम भारतीय जर्नल्समध्ये प्रकाशित करण्याचा निर्णय घेतला. डॉ. वाय सी सक्सेना, जे कि केजीएफ प्रयोगाचे सर्वे सर्वा होते, यांच्या मते बिभा यांचे काम आंतरराष्ट्रीय दर्जाचे असून भारतीय जर्नल्स मध्ये प्रकाशित करणे यामागील कारण अजूनही एक गूढच आहे. पीआरएलमधून निवृत्ती घेतल्यानंतर, बिभा चौधरी कलकत्ता येथे परतल्या आणि कोलकाता विद्यापीठ आणि साहा इन्स्टिटयूट येथील शास्त्रज्ञांच्या सहकार्याने उच्च ऊर्जा भौतिकशास्त्रावर संशोधन कार्य सुरू ठेवले. CR-39 सारख्या

सॉलिड स्टेट ट्रॅक डिटेक्टरचा वापर करून त्यांनी उच्च-ऊर्जा भौतिकशास्त्रावर संशोधन कार्य सुरू ठेवले.

२ जून १९९१ मध्ये कलकत्ता येथे वयाच्या ७७ व्या वर्षी बिभा चौधरी यांचे आकस्मित निधन झाले. त्यांचा शेवटचा पेपर 'Existence of charge phenomena in 56Fe + 27Al collisions at 1.88 A GeV' १९९० मध्ये इंडियन जर्नल ऑफ फिजिक्समध्ये प्रकाशित झाला होता. यावरून हे सिद्ध होते की, त्या शेवटच्या श्वासापर्यंत एक समर्पित शास्त्रज्ञ म्हणून कार्यरत होत्या.

बिभा चौधरी यांच्या निधनानंतर त्यांना दोन सन्मान प्रदान करण्यात आले आहेत. त्यांच्या सन्मानार्थ, आंतरराष्ट्रीय खगोलशास्त्र संघाने (International Astronomical Union) डिसेंबर २०१९ मध्ये बिभा चौधरी यांच्या नावावर एक 'पांढरा बटू तारा (White Dwarf) HD ८६०८१' या ताऱ्याचे नाव 'बिभा' ठेवले. असा सन्मान मिळालेल्या त्या भारतातील एकमेव महिला शास्त्रज्ञ आहेत. दुसरा सन्मान मार्च २०२० मध्ये मिळाला जेव्हा भारत सरकारच्या महिला आणि बाल विकास मंत्रालयाने प्रसिद्ध भारतीय महिला शास्त्रज्ञांच्या नावावर ११ अध्यासने स्थापन करण्याचा प्रस्ताव मांडला आणि बिभा चौधरी यांच्या नावावर भौतिकशास्त्र अध्यासनाची घोषणा करण्यात आली. सन २०१८ मध्ये त्यांचे चरित्र, 'A Jewel Unearthed: Bibha Chowdhuri' या नावाने एका जर्मन प्रेसने प्रकाशित केले.

बिभा चौधरी यांचे जीवन पुरुषप्रधान संस्कृतीत आव्हानांनी आणि संघर्षांनी भरलेले होते, विशेषतः १९ व्या शतकाच्या सुरुवातीला जन्मलेल्या एका महिलेसाठी, जेव्हा भारतात स्त्री शिक्षण पूर्णपणे अशक्य होते. त्या काळात पुरुषप्रधान भौतिकशास्त्राच्या क्षेत्रात संशोधन प्रकल्पात सामील होणे, स्वातंत्र्यपूर्व भारतात पुढील संशोधनासाठी एकटीने परदेशात प्रवास करणे, ही त्यांच्या अदम्य इच्छाशक्ती आणि दृढनिश्चयाचे उदाहरण आहे. बिभा चौधरी यांना त्यांच्या मृत्यूच्या ३० वर्षांनंतर अखेर योग्य सन्मान मिळाला.

बंगाली भाषेत बिभा म्हणजे 'प्रकाशकिरण'. त्यांची तेजस्वी प्रभा विश्वात कायमची नवीन पिढयांना प्रकाश आणि प्रेरणा देत राहील.

संदर्भ :

१. Suprakash C. Roy and Rajinder Singh, Bibha Chowdhuri – The First Woman Scientist at the TIFR, Physics News Vol 51 (1-2) 2021.

२. https://sd2.org/bibha-chowdhuri-a-woman-of-firsts-with-no-recognition/

३. Rajinder Singh, Suprakash C. Roy, A Jewel Unearthed: Bibha Chowdhuri, ISSN 0945-0815, Edited by Shaker Verlag, GmbH Germany 2018 - 158 páginas.

***

Do You Know ?

Bibha was once told there was **"no suitable research topic for women."**
– Despite this dismissal by Prof. D. M. Bose, she persisted until accepted into his lab, breaking gender barriers in 1930s Indian science.

While her mentor D. M. Bose is remembered as the father of cosmic ray research in India, Bibha's equal contribution was nearly erased from textbooks.

Exploring the Cosmos: The Pioneering Legacy of Physical Research Laboratory, Ahmedabad

Shashikant Shinde, PhD
Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

The Physical Research Laboratory (PRL) in Ahmedabad stands as a premier hub for space and allied sciences in India. Established on November 11, 1947, by the visionary Dr. Vikram Sarabhai, PRL began humbly—researching cosmic rays from Sarabhai's own residence. Today, it thrives as a National Research Institute supported by the Department of Space, Government of India, and continues to lead scientific inquiry across multiple disciplines.

Frontiers of Research

PRL has carved a niche in scientific exploration through its diverse departments:

- Astronomy & Astrophysics
- Atmospheric Sciences & Aeronomy
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With specialized observatories like the Udaipur Solar Observatory and the Mount Abu InfraRed Observatory, the institute is a cornerstone for astronomical observation and innovation.

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Additional educational initiatives include the UN School of Space Science, fostering global collaboration in astrophysics and satellite technologies, and the RESPOND Programme, which enables academic partnerships with PRL on cutting-edge projects.

For budding researchers, PRL offers Ph.D. programs in space sciences and theoretical physics, admitting scholars through national exams such as JEST, GATE, and CSIR-UGC NET. Undergraduate and postgraduate students can also gain hands-on experience through summer internships that delve into data analysis, observational techniques, and scientific methodologies.

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- scientists, or observational astronomers contributing to major discoveries.
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- In Space Engineering: Designing and optimizing satellite systems or working in remote sensing and quantum communication.
- In Academia & Research: Becoming professors, scientific researchers, or science communicators.
- In Policy & Exploration: Joining agencies like ISRO or NASA, or advising government bodies on space policy and strategy.

A Vision Beyond Earth

Through its world-class infrastructure, collaborative programs, and dedication to discovery, PRL continues to honour its founder's dream—fuelling humanity's quest to understand the universe. Its alumni light up scientific communities around the world, demonstrating that from a modest beginning in a private home, a galaxy of achievement is truly within reach.

Institute Images

Institute Logo

Campus Building

Telescope

Udaipur Observatory

Thaltej Campus

Mount Abu Observatory

PRL Main Building

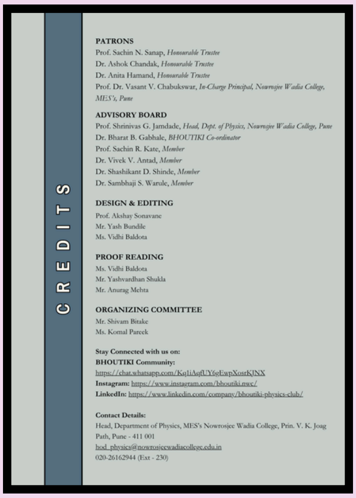
Image Courtesy: PRL, Ahmedabad

BHOUTIKI PRADNYA Inaugural Issue Release Ceremony

BHOUTIKI

Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

Cover Page



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The inaugural issue was ceremoniously released by Hon. Pro-Vice Chancellor of Savitribai Phule Pune University, Dr. Parag Kalkar, along with Hon. Trustee of MES, Prof. Sachin Sanap and Hon. Principal Prof. Dr. V. V. Chabukswar. Hard copies of BHOUTIKI PRADNYA are now available in the library of MES's Nowrosjee Wadia College and Soft copies of the first issue are available on our Instagram page and LinkedIn.

Whispers of the Universe

In silence deep, the cosmos spoke,
Through motion's law and Newton's stroke.
Electrons danced in orbits tight,
Their quantum paths defied our sight.

A photon's leap, so swift and strange,
No mass, yet travels every range.
Time bends near mass, the clocks run slow,
Einstein grinned—it's spacetime's flow.

Entropy whispers in closed halls,
Order breaks as chaos calls.
Yet in this dance of loss and gain,
Energy's song will still remain.

The Higgs once hid, then showed its face,
Granting mass and form and place.
In labs and minds, we chase the real,
With every law, the truths reveal.

So graduates, in fields you roam,
From particle pit to cosmic dome,
Hold fast to thought, to doubt, to spark—
For physics lights the deepest dark.

Amit Pokharkar, (Alumni, Physics)
Department of Physics, MES's Nowrosjee
Wadia College, Pune 411 001

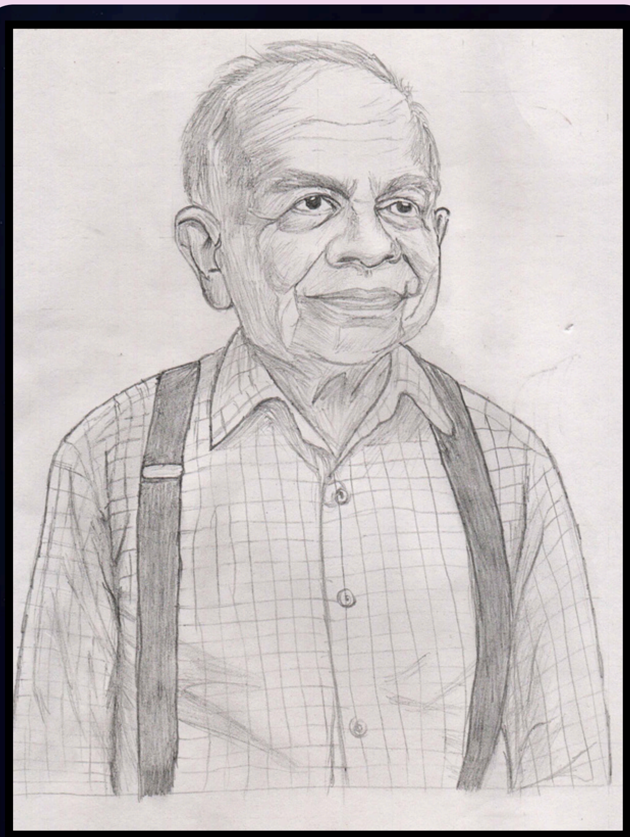
Unseen Force

Isaac Newton wondered why,
All things fell down from the sky,
A falling apple sparked off this notion,
Asking why all things go in a downward motion?

Gravity is the force that attracts,
It pulls things together, these are the facts,
The bigger the object, the stronger the pull,
So Earth pulls us all down, that is the rule!

Without gravity I could float in the air,
I could tumble and spin, without a care!
But I am not sure I'd like all that flying around,
I do like to keep my feet on the ground!

Sakshi Ghate, TYBSc
Department of Physics, MES's Nowrosjee
Wadia College, Pune 411 001



Rupali Khomne,
Department of Computer Science, MES
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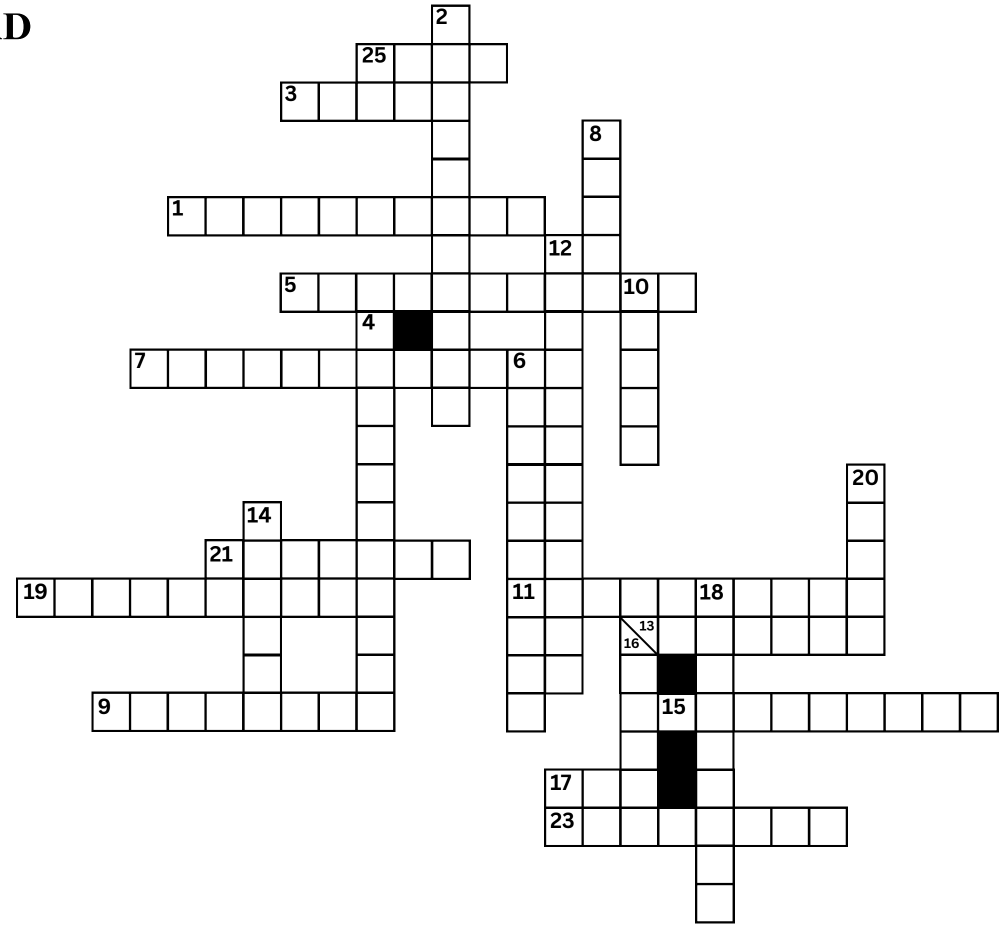
Prof. J. V. Narlikar

CROSSWORD



Across:

1. Type of wave particle duality experiment.

3. Elementary particle that acts as carrier of strong force.

5. Principal stating it is fundamentally impossible to know momentum & position of a particle simultaneously.

7. Type of entanglement in quantum mechanics.

9. Particle mediating gravity hypothetically.

11. Quantum state of definite energy.

13. Series forming a sum of harmonic, sinosoidal components by analysis of periodic function.

15. Concept related to quantum decoherence.

17. Wave-Particle duality's wave function.

19. Concept related to Black Hole entropy.

21. Unit of electric charge.

23. Star's fusion fuel.

25. An intrinsic angular momentum, a bowling technique.

Down:

2. Concept relate to Black Holes.

4. Mathematical Operation in quantum mechanics.

6. Phenomenon described by Navier-Stokes equation.

8. Particle associated with Higgs field.

10. Unit of magnetic field, strength, a car brand.

12. Relativity's time-slowing effect.

14. Smallest possible particle of light.

16. Unit of length equal to 10^{-15} meter. Name of a famous physicist .

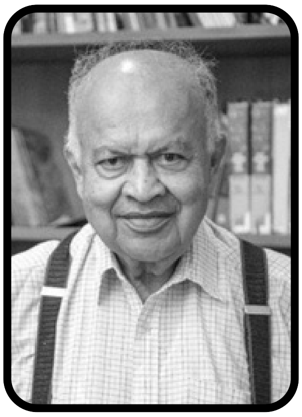
18. Cosmic explosions, a massive star's end.

20. SI unit of magnetic flux.

Komal Pareek, MSc-II
Department of Physics, MES's
Nowrosjee Wadia College, Pune 411 001

Tribute to Prof. J.V Narlikar, Dr. M. R. Shrinivasan, Dr. K. Kasturirangan & Prof. Rohini Godbole

Anurag Mehta, TYBSc
Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001



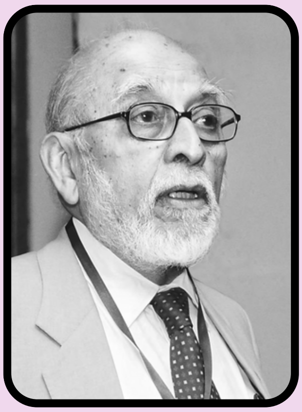
(1938 - 2025)

Prof. Jayant Vishnu Narlikar

Professor Jayant Vishnu Narlikar (JVN as we fondly refer to) left us peacefully in his sleep at his residence in Pune on May 20, 2025. This marks the end of an extraordinary chapter in Indian science. During his long, decorated research career, he inspired an uncountable number of young minds to take up science, shaped the careers of a large number of young scientists who went on to become world leaders in various aspects of Astrophysics and Cosmology.

As a researcher, he made unique and groundbreaking contributions to cosmology, challenged prevailing scientific orthodoxy, and took it as a mission to spread science and scientific temper to the broader public. He is best known for co-developing the Hoyle–Narlikar theory of gravity and for championing the steady-state theory in the initial days and quasi-steady-state theory of the universe in the later years. These theories challenged the widely accepted Big Bang model.

He was the founding director of the Inter-University Centre for Astronomy and Astrophysics (IUCAA) in Pune, which he built as a "role model" institute to promote the nucleation and growth of active groups in astronomy and astrophysics at Indian universities.

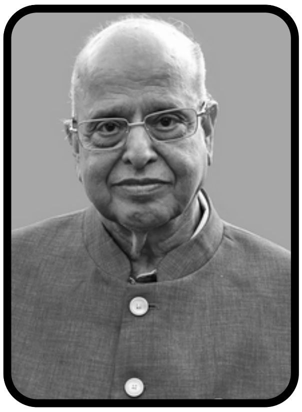


(1930 - 2025)

Dr. M. R. Srinivasan

Dr. Malur Ramasamy Srinivasan (5 January 1930 – 20 May 2025) was an Indian nuclear scientist and mechanical engineer. He played a key role in the development of India's nuclear power programme and the development of the Pressurized heavy-water reactor (PHWR). He received the Padma Vibhushan award in 2015.

Srinivasan joined the Department of Atomic Energy in September 1955. He worked with Homi Bhabha on the construction of India's first nuclear research reactor, Apsara, which went critical in August 1956. In August 1959, Srinivasan was appointed Principal Project Engineer in the construction of India's first atomic power station. Following this, in 1967, Srinivasan was appointed Chief Project Engineer at the Madras Atomic Power Station. In 1974, Srinivasan was appointed Director, Power Projects Engineering Division, DAE and then Chairman, Nuclear Power Board, DAE in 1984. In these capacities, he was responsible for planning, execution, and operation, of all nuclear power projects in the country. The Nuclear Power Corporation of India was created in September 1987, with Srinivasan as the Founder-Chairman. He was responsible for a total of 18 nuclear power units, of which seven are in operation, another seven under construction, and four still in the planning stages.



(1940 - 2025)

Dr. K. Kasturirangan

Dr. Krishnaswamy Kasturirangan (24 October 1940 – 25 April 2025) was a visionary Indian space scientist and a prominent architect of India's space programme. He served as the Chairman of the Indian Space Research Organisation (ISRO) from 1994 to 2003, during which India achieved major milestones, including the successful operationalisation of the Polar Satellite Launch Vehicle (PSLV) and the Geosynchronous Satellite Launch Vehicle (GSLV).

Prior to becoming ISRO Chairman, he was Director of the ISRO Satellite Centre, where he led the development of key satellite missions like INSAT-2, IRS-1A/1B, and India's first experimental Earth observation satellites Bhaskara I and II. His work laid the foundation for India's self-reliance in space technology.

Outside ISRO, Dr. Kasturirangan held several influential positions—he was Chancellor of Central University of Rajasthan, NIIT University, and Jawaharlal Nehru University, and served as a Member of Parliament (Rajya Sabha) from 2003 to 2009. He also contributed to national policy-making as a member of the Planning Commission of India, later known as NITI Aayog, and chaired the Karnataka Knowledge Commission.

His leadership in science and education was widely recognized, earning him the Padma Shri, Padma Bhushan, and Padma Vibhushan—India's three highest civilian awards.

Dr. Kasturirangan leaves behind a lasting legacy in Indian space science, policy, and education.

(1952 - 2024)

Prof. Rohini Godbole

Prof. Rohini Godbole (12 November 1952 – 25 October 2024) was a distinguished Indian theoretical physicist known for her influential work in particle physics, particularly on the Standard Model and physics beyond it. As a professor at the Indian Institute of Science (IISc), Bangalore, she made major contributions to the study of high-energy photons and collider phenomenology, shaping future directions in electron-positron collider research.

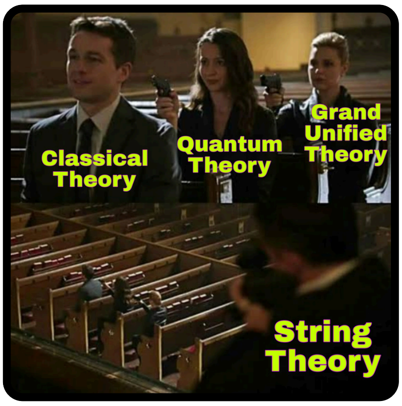
She was a fellow of all three Indian science academies and TWAS, and served on international scientific bodies such as the International Detector Advisory Group at CERN. Her commitment to both science and society was equally profound.

Beyond the lab and lecture halls, Prof. Godbole was a passionate science communicator and a vocal advocate for women in science. As Chair of the Women in Science Panel of the Indian Academy of Sciences and co-editor of the acclaimed Lilavati's Daughters, she championed greater visibility for women scientists across India.

Prof. Godbole leaves behind a legacy that spans groundbreaking physics, global collaboration, and unwavering advocacy for inclusivity in science.

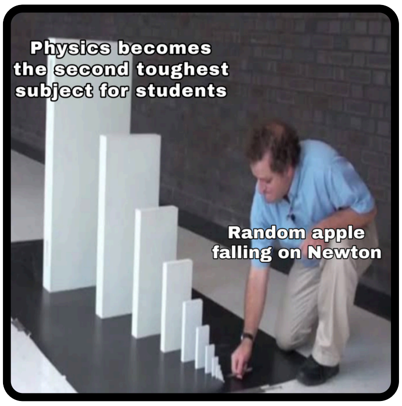
Physics Memes

Shubham Jadhav, MSc, SET
Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

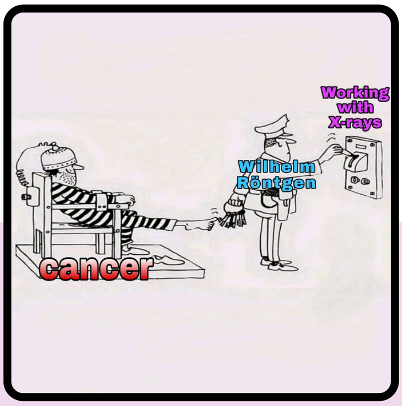


Chronology of Theories

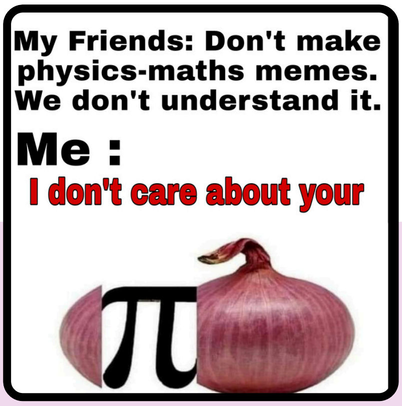
Students Transition



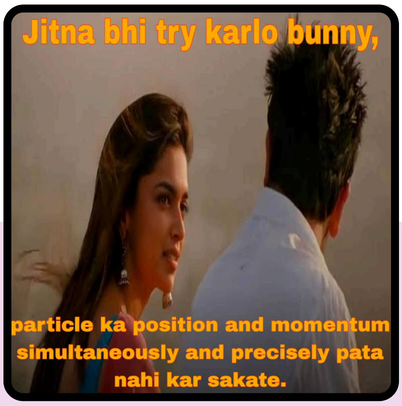
Domino Effect



Röntgen gave us X-rays.
Cancer came free of charge.

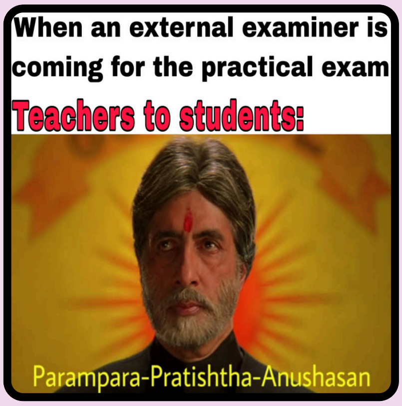


Irrational can be funny

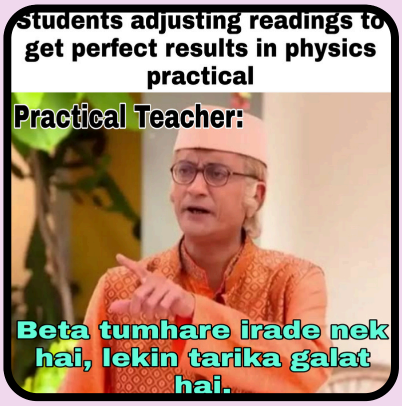


Heisenberg's principle in YJHD Naina's style

Filter on ; Noise gone



Gurukul ke teen niyam



Jab Practical Bane Jugad

The author is an Assistant Professor (Ad-hoc) in the Department of Physics at Nowrosjee Wadia College. An esteemed alumnus of our department, he specializes in Computational Physics and Theoretical Physics, while also excelling as a creative content creator.

Educational Trip

NIBE Ltd., Chakan & Vigyan Ashram, Pabal

Indian Institute of Geomagnetism, Alibaug Observatory

Instagram Daily Challenge Winners

Daily Challenge - April Edition

Rank	Name & Class	Membership ID
1	Sahithi Garimella (TYBSc, Zoology) Chanchal Agarwal (TYBSc, Physics)	BPC149 BPC136
2	Amit Pokharkar (Alumni, Physics)	BPC105
3	Rupali Khomne (Alumni, Physics)	BPC163

Daily Challenge - May Edition

Rank	Name & Class	Membership ID
1	Amit Pokharkar (Alumni, Physics)	BPC105
2	Vishwajeet Inamdar (TYBSc, Zoology) Sahithi Garimella (TYBSc, Zoology)	 BPC149
3	Rupali Khomne (Alumni, Physics)	BPC163

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