E-Magazine of Department of Physics, Victoria Institution (College)

FIZIKA

4th Volume

Date of Publication- 17th June, 2024

Editorial

Wonder is what we felt as a child when we looked up at night sky and beheld the sight of thousands of twinkling stars. Wonder is what we feel when we learn about the mysterious black holes. We feel wonderstruck each time we learn a little more of the ravishing magic of the universe. And the reason behind our wonder is none other than Physics. Physics isn't merely a subject, it's a profound exploration of the fabric of reality, an endless journey through the wonders and enigmas that define existence. Welcome to Fizika, E-Magazine of Department of Physics, Victoria Institution (College), where physics meets wonder.

Fizika was instigated in 2020-2021. We are overwhelm to announce that we have been successfully brought the fourth volume of Fizika. With each step taken, we've forged a remarkable path, yet there remains a vast path ahead of us. We extend our heartfelt gratitude to all the young writers whose insightful contribution has enriched this E-magazine.

In this issue we have topics like Medical Physics, Optical Instruments, James Webb Telescope, Exciton, Radiation Therapy, Glimpse of Medical Diagnostics, Hyperspace, String Theory, Our Universe, Quantum Mechanics, The Exciting Hunt for Exoplanets, Folkores. We bring you pioneering stories of physics and the relentless curiosity that drives scientific breakthroughs.

As you turn these pages, remember that physics is more than equations and experiments; it is the story of humanity's quest to understand our place in the cosmos. It is a narrative of discovery, wonder, and infinite potential. Welcome to Fizika — your guide through the boundless and awe-inspiring world of physics.

Lastly, we extend our heartfelt appreciation to our Principal madam for her invaluable support. We also express our profound gratitude to our respected Professors for their unwavering dedication and profound influence. In closing, we extend our warmest greetings to our esteemed readers wishing you all a captivating and enlightening experience as you journey through our pages .

- Dhriti Nath

Our Team

From left: Srijani, Maitreyee, Madhusree , Prerana, and Sulagna
Sem - VI

From left: Triparna, Dhriti, Akanksha and Ankita
Sem - IV

From left: Shweta ,Barnali, Sharqa , and Arshi,
Sem - II

Message from the Principal's Desk:

Dr. Maitreyi Ray Kanjilal,
Principal
Victoria Institution (College)

The E-Magazine, FIZIKA ,published by the students of the Department of Physics every year, highlights topics of contemporary Physics and other allied areas. Such initiatives are important in cultivating interest and motivating young students to take up research in both fundamental science and technology. I would like to congratulate the team of FIZIKA for the publication of the fourth volume of the E-magazine and wish it success in its future journey.

Message from the Department of Physics

With great pleasure, we the teachers of the Department of Physics Victoria Institution (College), congratulate our students for successfully publishing the fourth volume of the Annual E-Magazine "FIZIKA".
The magazine consists of myriad articles raging from medical physics to astrophysics, quantum mechanics and string theory. It also includes interesting write-ups on the use of optical instruments and stories pertaining to some important discoveries.
The articles are all well written and insightful. The E-Magazine reflects the creative potential and talents of our students which gives us immense pride.
We wish to acknowledge the help rendered by all students associated with "FIZIKA" and thank them profusely.
We extend our best wishes for the success of the E-Magazine.

Smt. Swarnalekha Bandyopadhyay

Dr. Gayatri Pal, HOD

Dr. Subhendu Chandra

Dr. Shinjinee Das Gupta

Dr. Atri Sarkar

Ms. Kathakali Biswas

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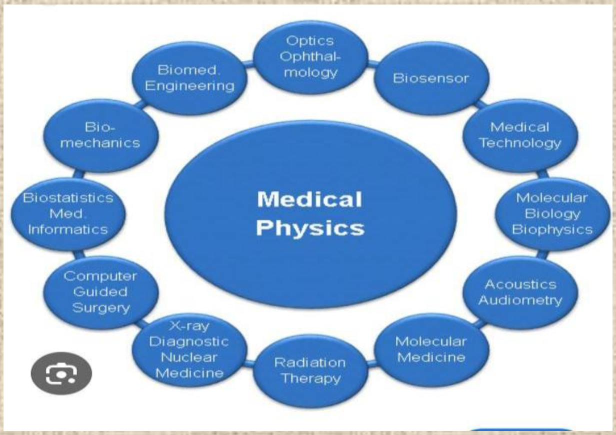
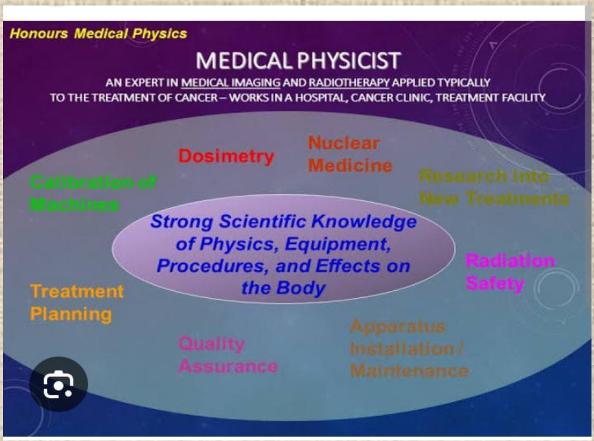
Medical Physics

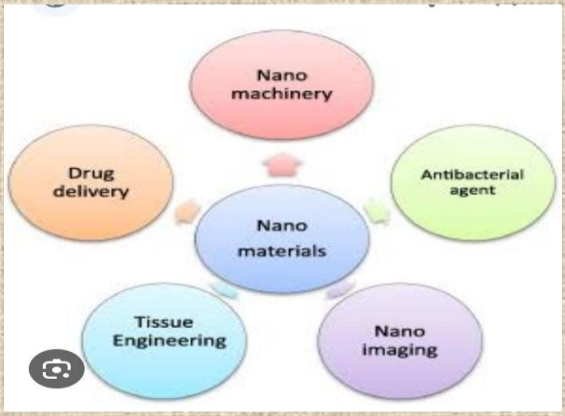
Madhushree Mukherjee, Sem - VI

Medical physics bridges the gap between physics and medicine, using the power of physics to revolutionize healthcare. This dynamic field focuses on applying physical principles to improve diagnosis, treatment, and research. From the intricate workings of MRI machines to the targeted application of radiation therapy, medical physics encompasses a vast array of technologies. These include medical imaging techniques like CT scans and MRIs, radiation treatment for cancer, nuclear medicine for targeted imaging and therapy, and dosimetry, the precise measurement of radiation dose. By ensuring the safe and effective use of these technologies, medical physicists play a critical role in optimizing patient care and advancing medical science.





Dr. Ramaiah Naidu was a nuclear physicist and medical scientist and radiologist who played a key role in establishing the foundation of medical physics in India.
This emerging and multidisciplinary field has a long history with many contributors of diverse expertise.



For example experts of nano-science hold promise for targeted drug delivery in medical physics using nanoparticles. Researchers are exploring various types of nanoparticles, including polymeric ones, to deliver drugs directly to tumors or other specific areas within the body.

Medical Physicist responsibilities:

1) To monitor machine installation by the manufacturer and provide assistance as needed.

2) Study and plan radiation treatments for cancer patients.

3) Develop new safety procedure and ensure the safety and quality.

<u>Subspecialities of Medical Physics</u>

1)Therapeutic medical physics: is a specialized field within medical physics that focuses on the application of physics principles and techniques to the treatment of diseases, primarily through radiation therapy. It plays a crucial role in the multidisciplinary approach to cancer treatment, applying physics expertise to improve patient outcomes through precise and effective radiation therapy.

2) Diagnostic Medical Physics : focuses on the use of various imaging techniques for the diagnosis and treatment planning of medical conditions. It is essential for the accurate diagnosis and effective treatment planning of medical conditions through the application of imaging technologies. It encompasses a wide range of responsibilities aimed at optimizing diagnostic imaging quality, ensuring patient safety, and advancing medical imaging science.

3)Nuclear Medical Physics : It focuses on the use of radioactive substances (radiopharmaceuticals) for diagnostic imaging and therapeutic purposes. It combines expertise in physics, biology, and medicine to apply radioactive materials for both diagnostic imaging and therapeutic treatments, contributing significantly to the field of nuclear medicine and patient care.

4)Medical Health Physics : It plays a crucial role in maintaining radiation safety and protecting the health of patients, healthcare workers, and the public in medical environments where ionizing radiation is used for diagnostic and therapeutic purposes.

American Association of Physicist in Medicine (AAPM): It is a scientific, educational and professional organisation of medical physics. It established in 1958. There are 8000 scientist practising clinically and ensure safety, accuracy, quality in the use of radiation in medical procedures.

The ever-evolving field of medical physics holds immense promise for the future of healthcare, offering even more precise diagnoses, targeted treatments, and a deeper understanding of the human body.

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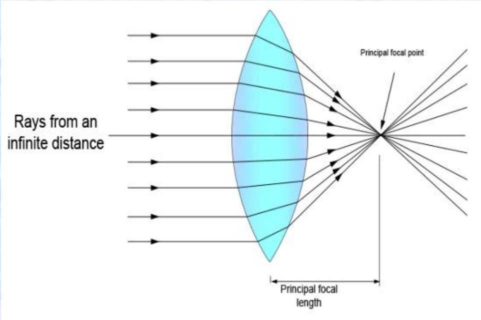
Optical Instruments: Observing World through the Optics

Maitreyee Maiti , Sem -VI

Optical Instruments are devices that employ one or more lenses for the light waves to process and pass through them to enhance the image formation or to analyze and diagnosis their properties. It helps to have a distinct and clear image of the object with fine details for observation.

The optical devices are made up with few components, includes lens, light detector and eyepiece. The lens converts the object to a desirable image for the user to view. The light detector converts the image into electrical signals for the computer to process. The eyepiece helps user to perceive the image formed.



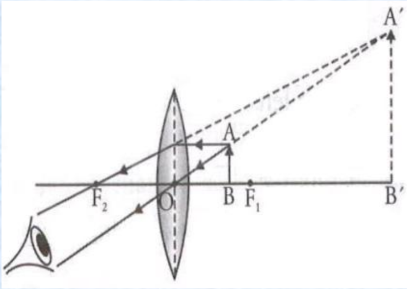
Optical instruments are divided into three main categories:

(a) Reflective:
Combination of mirrors to form magnified image.

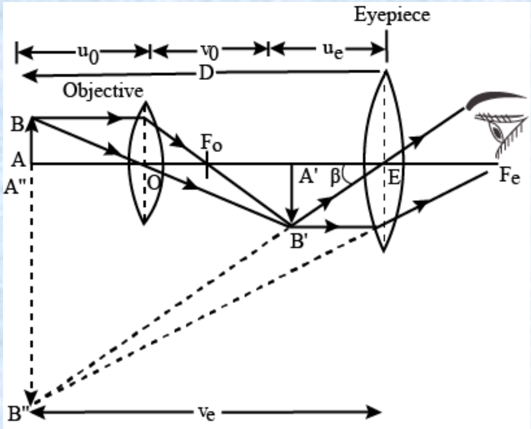
(b) Refractive:
Combination of lenses to form magnified image.

(c) Catadioptric:
Combination of lenses and mirrors to form magnified image.

(i) Magnifying Glass:
It is the simplest of all optical instruments. The lens is a made of converging lens which produces erect, virtual and enlarged images of the object. A well know experiment with magnifying glass is when sun rays (object at the focal point of the lens it catches fire.

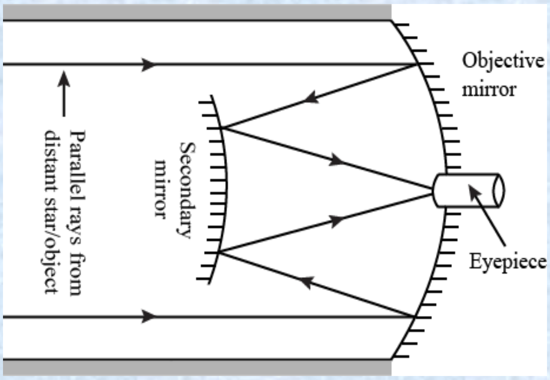


(ii) Compound microscope:
This instrument have minimum two lenses with more than one eyepiece lenses and objective lenses. The eyepiece lenses which is near the human eye, forms an enlarged image. While the objective lenses which is closer to the object, forms an enlarged image inside the microscope.

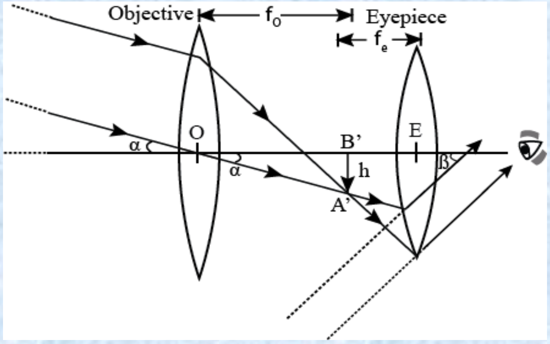


(iii) Telescope:

It is made up of convex lenses or concave mirror for the formation of images. It is used to form enlarged images of distant celestial bodies in space which appear very small. There are basically two types of telescopes i.e., reflecting and refracting telescopes. In Reflecting telescopes, concave mirror is used to collect and focus light to form an image while refracting telescopes uses convex lens to collect and focus light to form an image. In both telescopes eyepiece is used to enlarge the image.



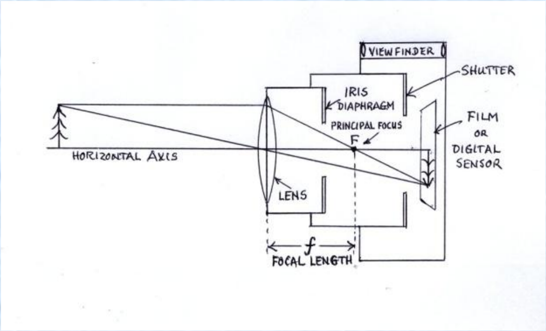
Reflecting telescope



Refracting telescope

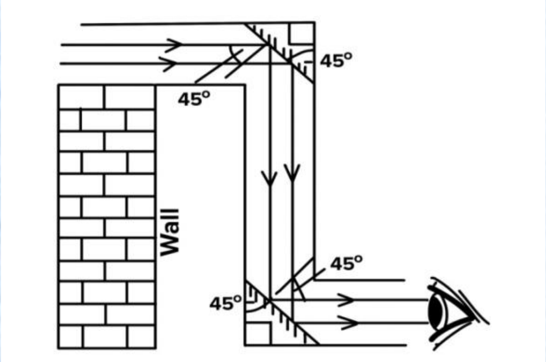
(iv) Camera:

It is used for the formation of images which are detected by electronic sensors for storing and also used for recording using a film. The light is passed through an opening of a camera called as aperture. When the light is passing through the lens, a reduced real image is formed. To bring the image into focus the lens is moved back and forth.



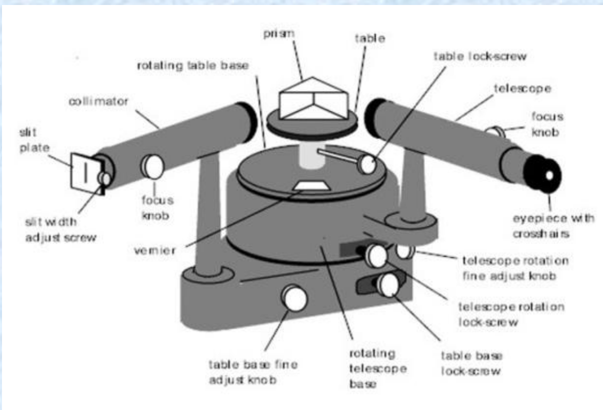
(v) Periscope:

It is an instrument which uses principle of reflection. Two parallel mirrors are place inside the periscope and are inclined at 45° to the inner surface of it. The light coming from the object incidents over the top mirror and is then reflected at an angle of 90° down the tube. The instrument is painted black to have a clear view of the image.



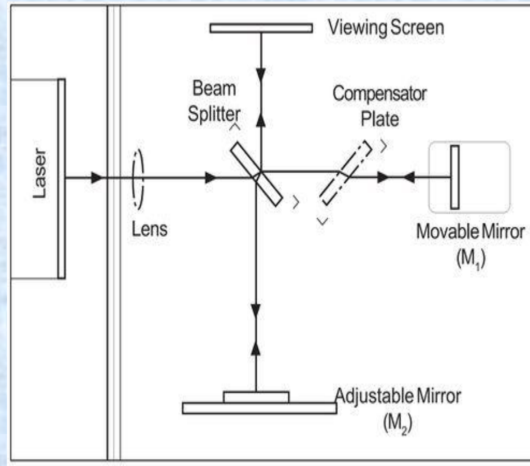
(vi) <u>Optical Spectrometer:</u>

It is used for detecting and analysing wavelengths of electromagnetic radiation for molecular spectroscopy and light properties. Used to observe the spectrum of light i.e., deflection caused by refraction through a prism or a diffraction through a grating.



(vii) <u>Interferometer:</u>

Optical device which uses the principle of interference of light waves. Light beam strikes the beam splitter and splits into two. Some of the beams due to some external influences i.e. refractive index changes in transparent medium and superposition of the two beams the beams give interference pattern. The spatial shape or the power of the resulting beam can be used for measurement. Types of interferometer are Mach-Zehder interferometer, Michelson interferometer, Fabry-Parot interferometer etc.



Optical instrument is essential in every aspect of our life as it can study various subjects like astronomy, physics, chemistry, and biology. It mostly plays a very vital role in the field of medicine. Another example of optical Instruments are microscopes, used for magnifying small things.

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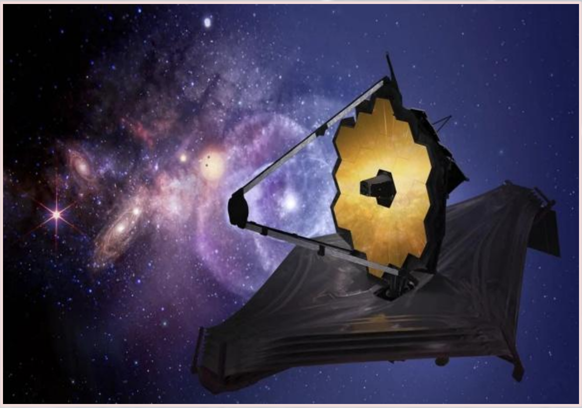
<u>James Webb Space Telescope : A Window into the Depths of Space</u>

Prerana Saha, Sem-VI

We wonder. It's our nature. How did we get here? Are we alone in the universe? How does the universe work? The James Webb Space Telescope (JWST) is an ambitious scientific attempt to answer these questions. It builds on the legacy of previous space telescopes to push the boundaries of human knowledge even more further, to the formation of the first galaxies and the horizons of other worlds. Explore the universe with Webb.

The James Webb Space Telescope (JWST) is a space telescope which is capable of observing the universe in infrared wavelengths. Its high-resolution and high-sensitivity instruments allow it to view objects too old, distant for the Hubble Space Telescope. It's advanced technology will allow it to study the early universe, the formation of stars and galaxies, and the atmospheres of exoplanets, among other things. JWST was successfully launched on December 25, 2021 on an Ariane 5 rocket from Europe's Spaceport in Kourou, French Guiana. In January 2022, it arrived at its destination, a solar orbit near the Sun–Earth L2 Lagrange point, about 1.5 million kilometers from Earth. The telescope's first image was released on 11 July 2022 to the public. JWST is currently in the constellation of Ophiucus. The telescope is named after James E. Webb, who was the administrator of NASA. The current Right Ascension is 16h 47m 12s and the Declination is -21° 23' 05". Right now, from the selected location (Greenwich, United Kingdom), JWST is not visible because it is below the horizon.



<u>Some Key Features of JWST:</u>

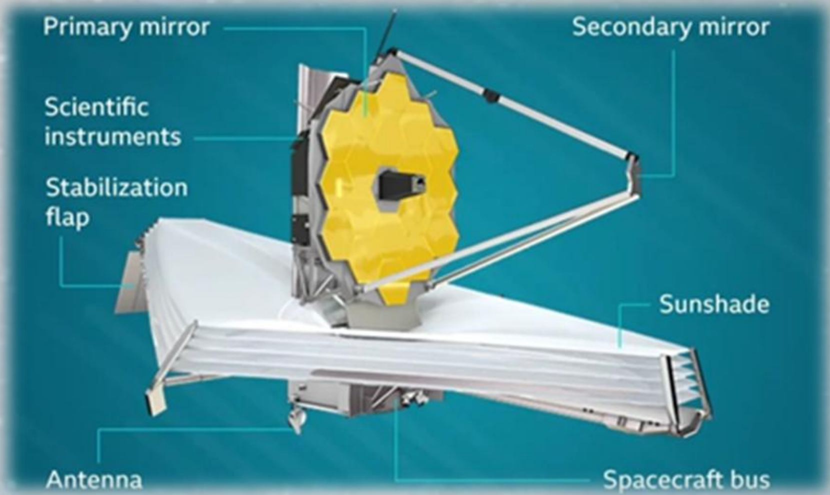
<u>1) Large Primary Mirror :</u> The JWST boasts a 6.5 m (21 ft)-diameter gold-coated beryllium primary mirror made up of 18 separate hexagonal mirrors, making it the largest space telescope mirror ever constructed. This large mirror allows JWST to gather a significant amount of light from distant celestial objects.

<u>2)Sunshield Protection :</u> To protect its sensitive instruments from the heat of the Sun and the Earth, the JWST is equipped with a five-layer sunshield roughly the size of a tennis court. This sunshield keeps the telescope and its instruments at cryogenic temperatures, essential for infrared observations.

3)Scientific Instrument : JWST carries four main scientific instruments:

- **Near InfraRed Camera (NIRCam) :** Captures high-resolution images in the near-infrared range (0.6 to 5 micrometers), crucial for studying the early universe and star formation.
- **Near Infra Red Spectrograph (NIRSpec) :** Analyzes light spectra from distant objects to determine their composition, temperature, and motion. It can observe up to 100 objects simultaneously.
- **Mid Infra Red Instrument (MIRI) :** Covers the mid-infrared range (5 to 28 micrometers) with both imaging and spectroscopic capabilities, essential for studying colder objects and dust-shrouded regions.
- **Fine Guidance Sensor/Near InfraRed Imager and Slitless Spectrograph (FGS/NIRISS) :** Provides precise pointing information for the telescope and performs scientific observations, including exoplanet detection and characterization.

4)Spacecraft Bus : The spacecraft bus is a primary support component of the JWST, serving as the structural and functional backbone that supports the observatory's various systems. It's hosting a multitude of computing, communication, electric power, propulsion and structural parts.



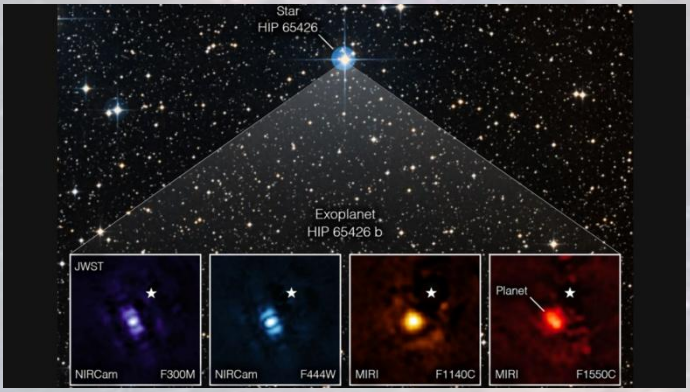
Mission & Goals of JWST:

JWST is looking for four main things. These are the major science goals of the mission:

- To identify and observe the first galaxies that formed in the early universe, dating back to just a few hundred million years after the Big Bang.
- To study the formation and also the evolution of galaxies from their formation to the present day.
- To investigate the formation and early development of stars and planetary systems.
- To study the formation ,composition, and potential habitability of planetary systems, including those around other stars and within our own solar system.

Discoveries of JWST:

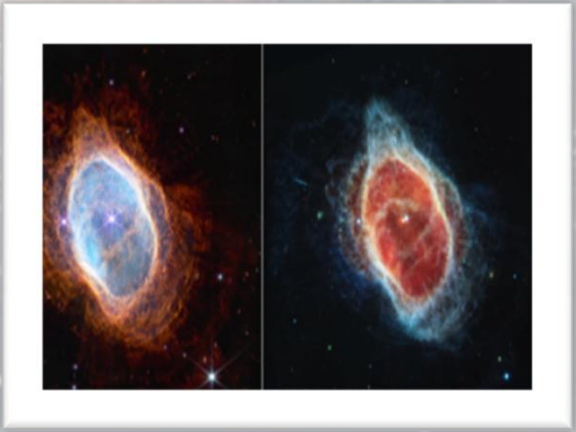
The ground in Kourou, French Guiana literally shook as the rockets on the Ariane 5 launch vehicle ignited the morning of Dec. 25, 2021. The roar signaled the start of the JWST's month-long journey to its current home some 930,000 miles (1.5 million kilometers) from Earth. Although it took scientists and engineers an additional five months to get the telescope ready for action and the wait was worth it. In the two years since its launch, JWST has transformed our view of the universe. Here's a look at the JWST discoveries that altered our understanding of the universe:



JWST has discovered six enormous "universe breaker" galaxies, containing what seemed to be almost as many stars as the Milky Way, dating to just 500 million years after the Big Bang. The telescope's powerful eye has also revealed glimpses of completely new, unexplainable objects. After being trained on the Orion Nebula, this telescope found 42 pairs of Jupiter-mass binary objects, or "JuMBOs" — Jupiter-sized planets drifting through space in pairs, some as far apart from each other as 390 times the distance between sun and the Earth. It has found three bright objects that could possibly be "dark stars" . JWST has found two old black holes in the universe. The first, CEERS 1019 which had a mass 10 million times that of our sun and it was found by the JWST just 570 million years after the Big Bang, making it the oldest black hole ever spotted at the time of its discovery in April, 2023.

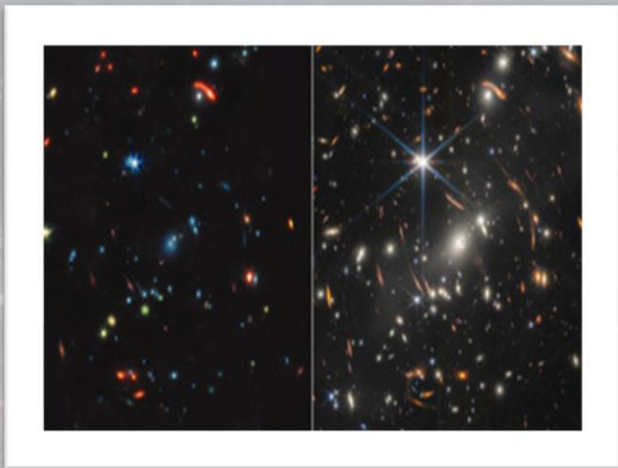
JWST has also discovered an even older massive black hole just 440 million years after the universe began. The observations of JWST have provided unprecedented detail in protoplanetary and tantalizing clues of precursors to life. Around the nearby star Fomalhaut, this telescope found three nested belts of warm dust, suggesting that planets shaped the disk. Webb has captured its first direct image of an exoplanet. JWST has discovered carbon dioxide and methane in the atmosphere of a nearby exoplanet named K2-18 b, which circles a cool star 120 light-years from Earth and is larger than our planet but is smaller than the giant planets in our solar system. It has found dust in a galaxy just 1 billion years after the Big Bang. The dust has a unique chemical fingerprint, suggesting it may be a mixture of graphite- or diamond-like grains created in the earliest stars. It opens a new path into dust production and galaxy formation. It has discovered a small asteroid embedded in the main asteroid belt between Mars and Jupiter. Another addition to the JWST's long list of cosmic distance records is its discovery of the most distant gravitationally lensed object ever seen — an "Einstein ring" produced by the warping of light from a distant galaxy around a mysteriously dense foreground galaxy.

Images taken by JWST:



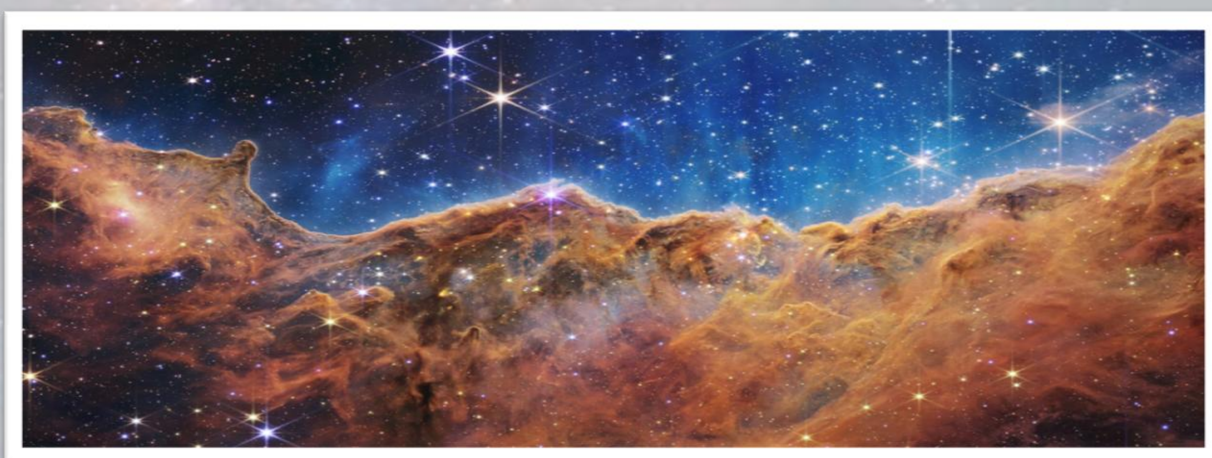
Southern Ring Nebula

<u>**Images taken by JWST:**</u>



Deep Field

Stephan's Quintet



"Cosmic Cliffs" in the Carina Nebula

Conclusion:

James Webb Space Telescope stands as a transformative instrument in the field of astronomy, offering unprecedented insights into the earliest epochs of the universe, the formation of stars and planets, and the potential for life beyond solar system. Its cutting-edge technology and groundbreaking discoveries are opening new frontiers in astronomy, offering profound insights into the origins and evolution of galaxies, stars, and planetary systems. It also inspires future generations of scientists and engineers to explore the farthest reaches of space. As we continue to unlock the secrets of the universe, the JWST will remain at the forefront of this exciting journey, heralding a new era of astronomical exploration.

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Exciton in a Nutshell

Srijani Banerjee, Sem -VI

In some applications it is useful to consider electronic excitation as if a quasi-principle, capable of migrating, were involved. This is termed as exciton. An exciton can form when an electron from the valence band of a crystal is promoted in energy to the conduction band e.g., when a material absorbs a photon. Promoting the electron to the conduction band leaves a positively charged hole in the valence band. Here 'hole' represents the unoccupied quantum mechanical electron state with a positive charge, an analogue in crystal of a positron. Because of the attractive coulomb force between the electron and the hole, a bound state is formed, akin to that of the electron and proton in a hydrogen atom or the electron and positron in positronium. Excitons are composite bosons since they are formed from two fermions which are electron and hole.

Wannier-Mott Excitons

Columbic interaction between the hole and the electron is given by

$E_{EX} = -e^2 / \varepsilon r$.

The exciton energy is then given by,

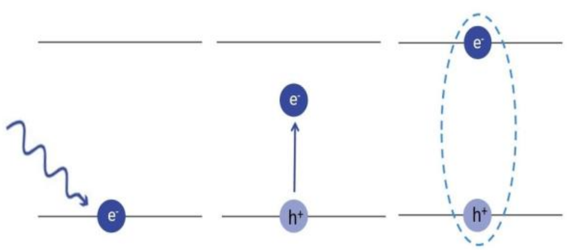
$E = E_{ION} – E_{EX}/n^2$, n = 1,2,..

E_{ION} is the energy required to ionize the molecule, n is the exciton energy level.

E_{EX} = 13.6 eV μ/m∈ and μ is the reduced mass.

In semiconductors, the dielectric constant is generally large. Consequently, electric field screening tends to reduce the Coulomb interaction between electrons and holes..The result is a Wannier–Mott exciton, which has a radius larger than the lattice spacing. Small effective mass of electrons that is typical of semiconductors also favors large exciton radii. As a result, the effect of the lattice potential can be incorporated into the effective masses of the electron and hole. Likewise, because of the lower masses and the screened Coulomb interaction, the binding energy is usually much less than that of a hydrogen atom, typically on the order of 0.01eV.

This type of exciton was named for Gregory Wannier and Nevill Francis Mott.



Formation of excitons through absorption of a photon

Wannier–Mott excitons are typically found in semiconductor crystals with small energy gaps and high dielectric constants, but have also been identified in liquids, such as liquid xenon. They are also known as large excitons.

In organic materials two models are used: the band or wave model (low temperature, high crystalline order) and the hopping model (higher temperature, low crystalline order or amorphous state). Energy transfer in the hopping limit is identical with energy migration.

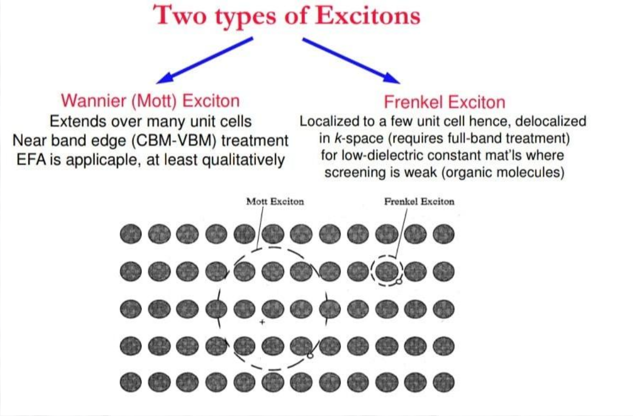
Frenkel Excitons

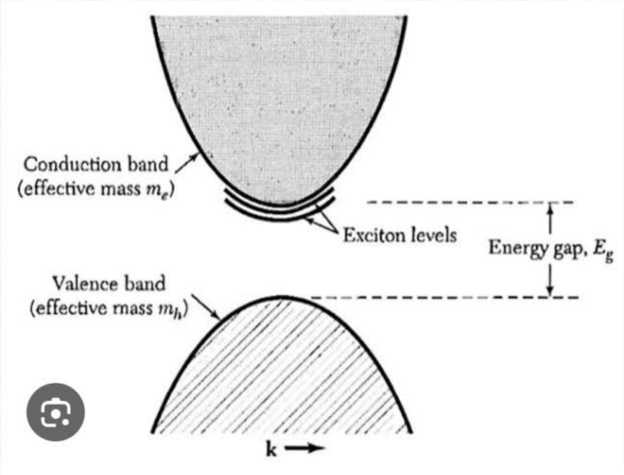
In materials with a relatively small dielectric constant, the Coulomb interaction between an electron and a hole may be strong and the excitons thus tend to be small, of the same order as the size of the unit cell. Molecular excitons may even be entirely located on the same molecule, as in fullerenes. This Frenkel exciton, named after Yakov Frenkel, has a typical binding energy on the order of 0.1 to 1 eV.

Frenkel excitons are typically found in alkali halide crystals and in organic molecular crystals composed of aromatic molecules, such as anthracene and tetracene.

Another example of Frenkel exciton includes on-site d-d excitations in transition metal compounds with partially filled d-shells. While d-d transitions are in principle forbidden by symmetry, they become weakly-allowed in a crystal when the symmetry is broken by structural relaxations or other effects. Absorption of a photon resonant with a d-d transition leads to the creation of an electron-hole pair on a single atomic site, which can be treated as a Frenkel exciton.

Excitonic properties will often determine the potential application of a material in optoelectronic devices, for example as photovoltaic, light-emitting diodes or even as lasers.





Charge transfer exciton

There exist another type of excitons apart from the Frenkel exciton or a small-radius exciton whose spatial extension of is approximately restricted to a single unit cell and the Wannier-Mott exciton or a large-radius exciton. where electron and hole are separated over many lattice constants. The third type can be formed in ionic crystals and are known as charge transfer exciton.

One can imagine its creation as follows: An electron is transferred from a lattice anion to a nearest neighbour cataion, thereby creating there a maximum of the electron charge density. The radius of the charge transfer exciton can therefore be some what larger than that of the Frenkel exciton.

Frenkel excitons are localized at a specific atom or molecule, and their movement through the crystal is limited to a hopping mechanism. They occur in molecular crystals whereas, for Wannier-Mott excitons the wavefunction is strongly delocalized and the exciton can move freely inside the crystal.

The van der Waals interfaces of molecular donor/acceptor or graphene - like two-dimensional (2D) semiconductors are central to concepts and emerging technologies of light-electricity inter-conversion. Examples include, among others, solar cells, photo-detectors, and light emitting diodes. A salient feature in both types of van der Waals interfaces is the poorly screened Coulomb potential that can give rise to bound electron–hole pairs across the interface, i.e., charge transfer (CT) or interlayer excitons.

Excitonic Effects in Modulation of Optical Properties

1. Absorption Spectra: Excitonic effects modify the absorption spectrum of materials. Instead of a single absorption peak corresponding to the energy gap between the valence and conduction bands (in the case of semiconductors), multiple peaks appear due to exciton formation. These peaks depend on the exciton binding energy, which influences the wavelength of absorbed light.

2. Photoluminescence: Excitons play a key role in photoluminescence, where absorbed photons promote electrons to higher energy states. When excitons recombine, they emit photons, affecting the material's emission spectrum.

3. Charge Transport: In optoelectronic devices, such as solar cells and light-emitting diodes, excitons affect charge transport. Excitons can either dissociate into free electrons and holes or recombine, influencing device efficiency.

4.Optical Modulators: Excitonic effects can be exploited to modulate optical properties. For example, by applying an external electric or magnetic field, the exciton binding energy can change, altering the material's absorption and emission characteristics. This property is crucial in designing devices like modulators and switches for optical communication and computing.

5. Quantum Dots and Nanomaterials: In nanostructures like quantum dots, excitonic effects dominate due to quantum confinement effects. The discrete energy levels and strong Coulomb interactions lead to unique optical properties, including size-tunable absorption and emission spectra.

As an example of the excitonic effects and optical properties we can consider the work on the graphene-like hexagonal boron carbide (BC) monolayer carried out by MV Durnev and MM Glazov. They have investigated the system through ab-initio many-body calculations with GW approximation alongwih Bethe-Salpeter equation (BSE) approach. They obtained that the planar BC has direct band gap with metallic character of 3.18 eV and the optical absorption spectrum is dominated by discrete excitonic peaks. They explained the formation of such bound excitons as the enhanced electron-hole interaction in low-dimensional materials.

Conclusion

Excitons are critical in modern optoelectronic devices. Reduced dimensionality increases the binding energy so excitons exists at room temperature. Thus, controlling excitonic effects are essential for developing advanced materials with tailored optical properties for various technological applications, ranging from LED to photovoltaics and quantum computing.

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Radiation Therapy

Sulagna Dey, Sem - VI

There is a famous branch of Applied Physics which deals with the use of ionizing or non-ionizing radiation in the diagnosis and treatment of disease, Radio Therapy. It is used to treat a wide variety of cancers. Radiation therapy in cancer was started with Wilhelm Conrad Roentgen, who discovered X-rays in 1895. Its early development was initiated by Marie Curie, a physicist and chemist who conducted pioneering research on radioactivity. This cancer treatment uses high-energy particles or waves to kill cancer cells. Radiation therapy works by damaging the DNA in cancer cells, causing them to die.

Depending on the source of Radiation, Radio Therapy is of two types-

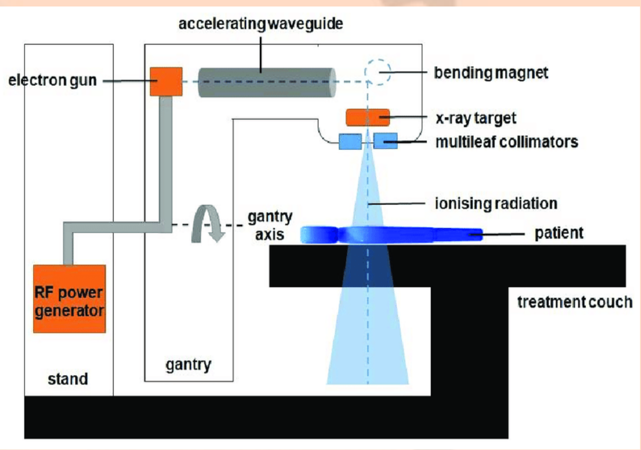
a. Teletherapy: EBRT (External Beam Radiotherapy), source is at a distance.
b. Brachytherapy: source is nearer to the patient.

Brachytherapy is divided into 3 types:
•Interstitial (into the tissue): Ca Prostate, Ca Breast
• Intracavitatory (accessible cavity): Accessible tumors like Ca Cervix
• Mold (Superficial cancers): Penis, Eye cancers

Teletherapy uses a Cobalt machine and LINAC (Linear Accelerator).-

1.The Cobalt machine produces an artificial radioisotope (Co),whose Half-life is 5.2 years.

2.LINAC does not need any radioisotope, the fast moving electron beam generates radiation used for radiotherapy.



LINAC

The Medical linear accelerator(LINAC) uses microwave technology to accelerate electrons in the "wave guide" of the accelerator. These electrons get collided with a heavy metal target to produce high-energy x-rays. This X-rays exit the machine to conform to the shape of the patient's tumor and it's directed by the customized Multi-leaf Collimator is used to shape the beam. Lasers are used to assure the patient's position. Radiation is delivered to the tumor by rotating the gantry of LINAC and moving the treatment couch.

X-rays generated by LINAC have various energies. They are: Ortho voltage <Super voltage<Mega voltage. [Penetration is directly proportional to energy]
Eg: A patient with carcinoma of pancreas, tumor is removed and the residual cells are to be killed which are superficial. Less energy or less permeable rays are enough. Hence, electron beam or ortho voltage is used.

Radiation treatment going inside the body is called Brachytherapy. During this therapy, a small solid implant is placed close to the cancer. To prevent the damage of healthy cells by Radiotherapy ,Brachytherapy is used basically. Interstitial Brachytherapy has no cavity,
To insert the radioactive source, After loading is the technique to be followed. Empty shell is put into the tissue, through which a robotic arm, a Lead-shielded storage container, sends the cable and automatically loads the shell. It reduces the manual handling of radioactive materials.

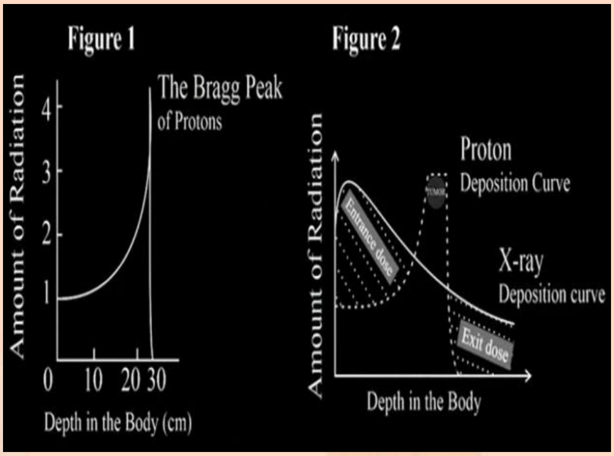
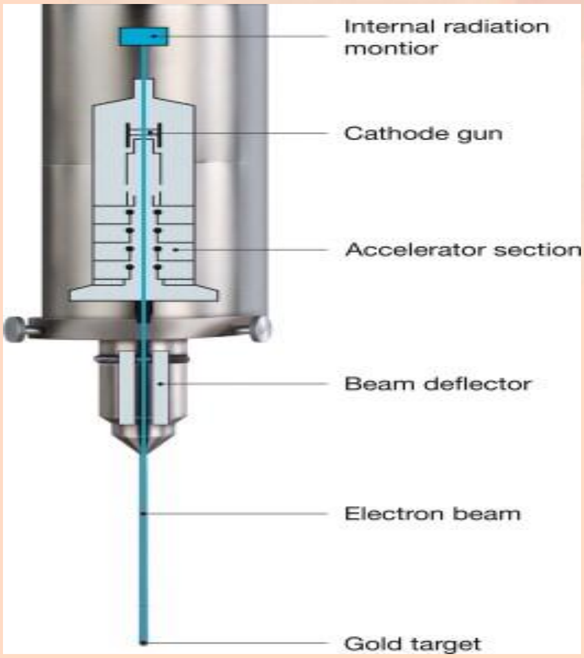


Image of Comparison between X-rays and Bragg peak



Brachytherapy

Besides X-rays ,Proton beams, neutrons, Gamma and beta rays are also used. In a proton beam, velocity is inversely proportional to dose given to the body.
As the beam travels deeper into the body, the velocity decreases and the dose increases suddenly.
Superficial structures are protected when proton beams are used.
Targeted pencil beams like radiotherapy can be given.
It affects only the tumor, surrounding cells are protected.

Example: A child with a brain tumor is given proton beam therapy, because the surrounding cells are not to be affected.

How radiation therapy is used in people with cancer

A. Primary treatment

B. Before surgery, to shrink a cancer. This is called Neoadjuvant therapy.

C. After surgery, to stop the growth of any remaining cancer cells. This is called Adjuvant therapy.

D. With other treatments, such as chemotherapy, to destroy cancer cells.

After radiation therapy, imaging tests is occurred to see if the cancer is shrinking. Sometimes the cancer responds to treatment right away. Other times it may take weeks or months to see the treatment working.

Radiotherapy not only targets cancerous cells but also prevents Damage to normal cells. Techniques used to prevent Damage of normal tissues:

1.Gating

2.3DCRT(3-Dimensional Conformal Radiation Therapy)

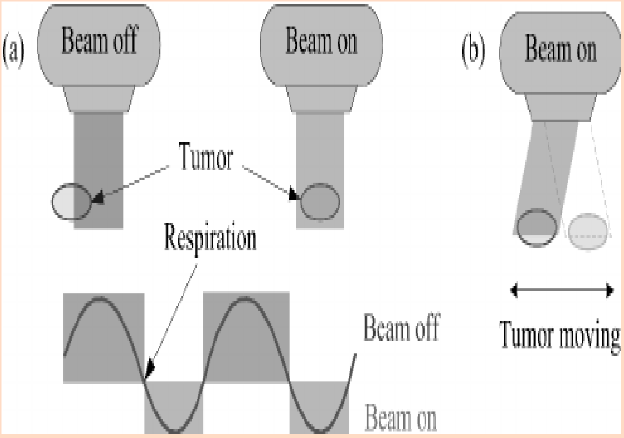
3.IMRT(Intensity Modulated Radiation Therapy)

4.VMAT(Volume Modulated Are Therapy)

5.IGRT(Image Guided Radiation Therapy)

6.Gamma Knife:

It comes under Stereotactic radiotherapy or surgery (SRS).Gamma rays are used to remove the tumor cells. Gamma knife emits multiple radiations over the coordinates placed on the tumor site.
Rays get focussed on the tumor site and ablated.

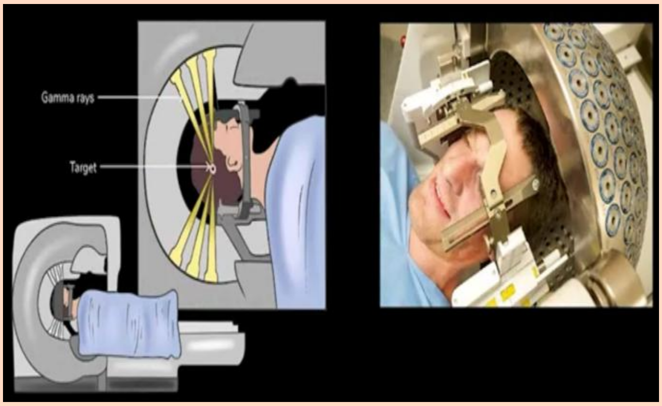


Gating

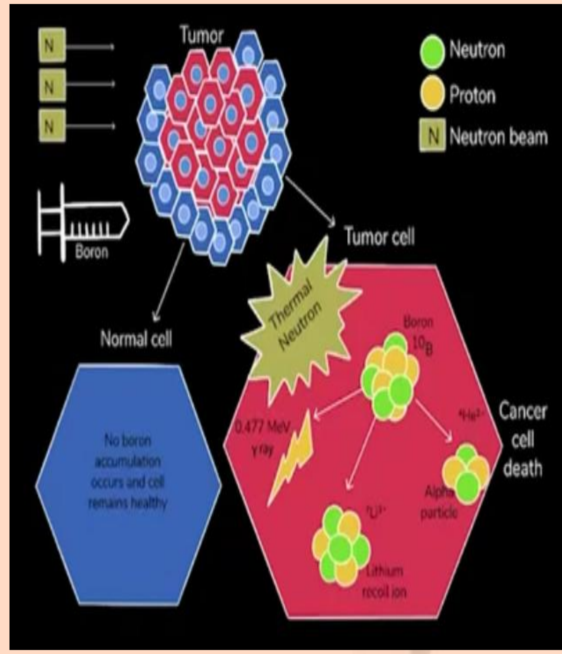
7.Cyberknife:
Stereotactic Body Radiotherapy (SBRT).It uses x-rays (LINAC).Used for Localized early stage cancers.

8.NCT (Neutron Capture Therapy):
Used for brain tumors.

Boron is injected (BPA), which is taken up not healthy cells. Thermal neutron is exposed, which is captured. This interaction generates alpha particles cell.

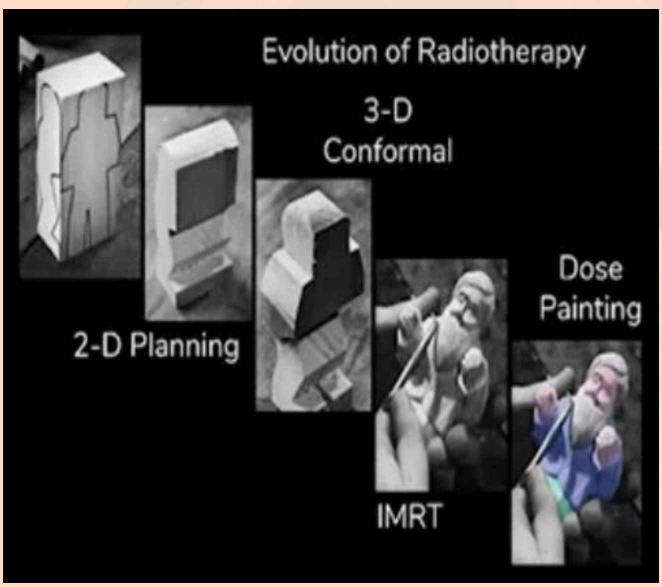


Gamma knife



Neutron capture Therapy

Radiotherapy in Cancer is an evolutionary contribution of Radiation-Physics. More research works are ongoing in this sector for betterment of Medical Sciences in upcoming future.



<u>Interesting Facts</u>

•First radioisotope used in humans was Radium-226.
It produces Radon (decay compound), which causes carcinoma of lungs. It emits alpha, beta, gamma rays.
• Radioisotopes with shorter half-lives can be used as permanent implants in Brachytherapy. These decay on their own.
• Radioisotopes with longer half-lives can be used as temporary implants in Brachytherapy.

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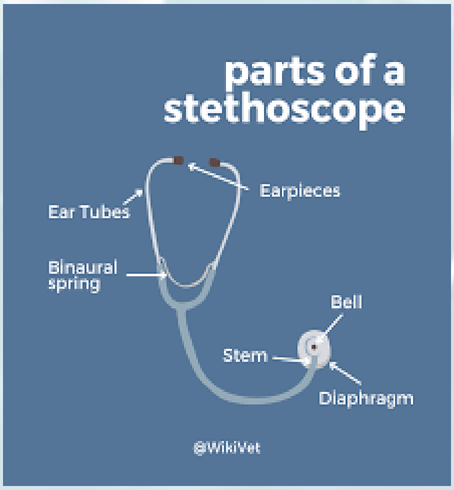
Medical Physics: A Glimpse of Medical Diagnostics through the Eyes of Physics

Akanksha Roy, Sem-IV

The role of Physics in the field of medicine is undeniably important. From the principle of a Stethoscope to the science behind Prosthetic equipments, Physics has always been more than just an aid to medicine. Medical Physics fulfils a key demand in medicine, in biological and medical research, and in optimization of certain health related activities. It includes areas such as Radiotherapy physics, Diagnostic Radiology Physics, Nuclear Medicine Physics and Radiation Protection. Other areas of interest in Medical Physics include the measurement of ionizing radiation, magnetic resonance imaging, application of lasers, ultrasound, etc.

A Stethoscope works on the principle of FLUID DYNAMICS and WAVES. The stethoscope consists of a tube, a chest piece and an earpiece. The Chest piece has a membrane on one of its two sides, also known as a diaphragm.

The chest beat of a person is heard by placing the chest piece on the chest. This is made possible by the LONGITUDINAL WAVES, which undergo continuous compressions and rarefactions. When chest piece is placed on the chest, the membrane of the diaphragm starts vibrating, because sound waves start hitting the sensitive diaphragm.



These vibrations are detected by the air present inside the tube which transmits the wave to the earpiece.

Now, the sound of the heartbeat is so low, that it needs to be amplified to reach the ears. The amplification happens when the waves travel from the diaphragm to the ear piece. It's interesting to note that the amplification of the sound waves is based on principle of Fluid Mechanics. The famous equation of continuity is used for the amplification of the waves.

$$A_1 * V_1 = A_2 * V_2$$

where A_1 and A_2 are the two ends of the tubes respectively, and V_1 and V_2 are the velocities with which the sound waves travel on the two sides of the tube respectively. The cross sectional area of the Diaphragm is greater than the area of the earpiece. There is a difference in the areas as well as the velocities. The area with larger cross sectional area has smaller velocity while the smaller area has higher velocity. The sound waves travel to the earpiece and hit it with higher velocity, thus amplifying the Sound Waves.

This was the case of heartbeat which has a higher pitch. But how does the stethoscope sense the vibrations of blood flowing through the arteries, which have very low pitches?

For this, the other side of the chest piece known as the Bell is used. While checking the arteries, the bell is placed on the skin. Since the bell has no membrane, it itself acts as the diaphragm. When even a minute vibration happens, the bell detects it and the sound waves are amplified in a similar way mentioned before.
This is the main concept behind A Stethoscope

Introduction to Electrocardiogram

The human heart is able to generate an electrical signal and it uses this electrical signal to create the muscular contraction needed to pump all the blood through the organs and tissues of our body. Physicians can actually study and analyze the electrical signal that the heart produces. If they connect electrodes to the surface of the skin at particular points (around the heart, the arm and the legs) and then connect the wires of the electrodes to a special device (some sort of voltmeter), they can then create a graph called an electrocardiogram. An electrocardiogram is a graph of the voltage that the heart creates (the y-axis is the voltage while the x-axis is the time). The physician can then study this electrocardiogram to see whether or not there is some abnormality in the persons heart.

Depolarisation and Repolarisation

The conduction system of the heart is responsible for generating electrical signals that cause the heart to contract and relax. The depolarization and repolarization of these cells play a crucial role in this process. Depolarization is the process by which the cells of the heart become less negative and contract. When the cells are at rest, they are negatively charged or polarized. However, when an electrical impulse is generated, the cells become depolarized. This occurs when the concentration of ions changes, specifically when sodium ions rush into the cells. The sodium ions move into the cells through ion channels, which are specialized proteins embedded in the cell membrane.

Once the sodium ions enter the cells, they cause the cells to become positively charged, which results in the depolarization of the cells. This causes the cells to contract and push blood through the heart. After depolarization and contraction, the cells need to relax, which is referred to as repolarization. Repolarization is the process by which the cells return to their negatively charged state. This occurs when the cell membrane becomes more permeable to potassium ions, which exit the cell. The loss of positive ions from the cell causes the cells to become negatively charged again, leading to relaxation. The process of depolarization and repolarization creates the electrical activity of the heart, which is represented as a PQRST waveform on an electrocardiogram (ECG).

The heart's conduction system is like the electrical wiring of a building. It controls the rhythm and pace of your heartbeat. Signals start at the top of your heart and move down to the bottom. Your conduction system includes:

Sinoatrial (SA) node: Sends the signals that make your heart beat.

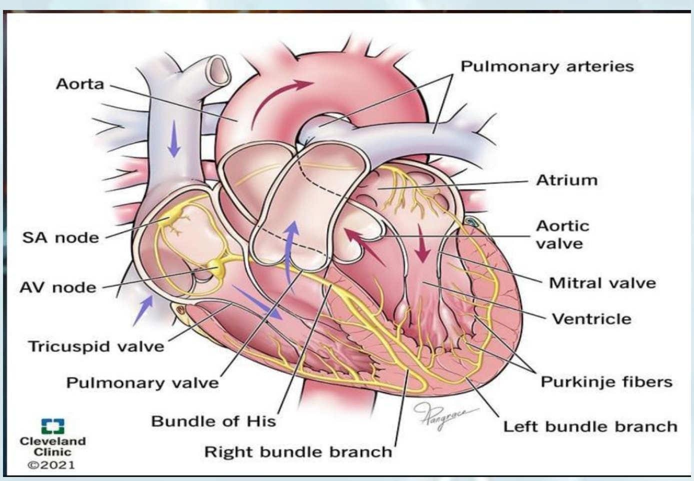
Atrioventricular (AV) node: Carries electrical signals from your heart's upper chambers to its lower ones.

Left bundle branch: Sends electric impulses to your left ventricle.

Right bundle branch: Sends electric impulses to your right ventricle.

Bundle of His: Sends impulses from your AV node to the Purkinje fibers.

Purkinje fibers: Make your heart ventricles contract and pump out blood.



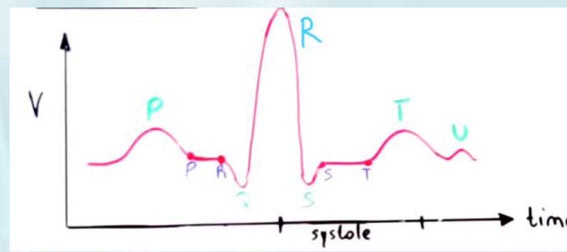
Mechanism

The sinusoidal node of the heart generates signal which then moves through the two atria and the Atrioventricular node.

The AV node delays the signal and then sends it through the Bundle of His and Purkinje Fibres, which causes the simultaneous movement of the ventricles.

If we connect two electrodes onto the surface of the skin at particular points, around the heart, we can pick up and read this electrical signal using a special device. This electrical signal can can be graphed(Voltage Vs Time) and this graph is called Electrocardiogram.

P WAVE – The Cardiac cells within the SA Node depolarize an action potential on the upper right atrium of the heart. As it spreads out through the conduction channels in the right and the left atria, it causes them to contract.

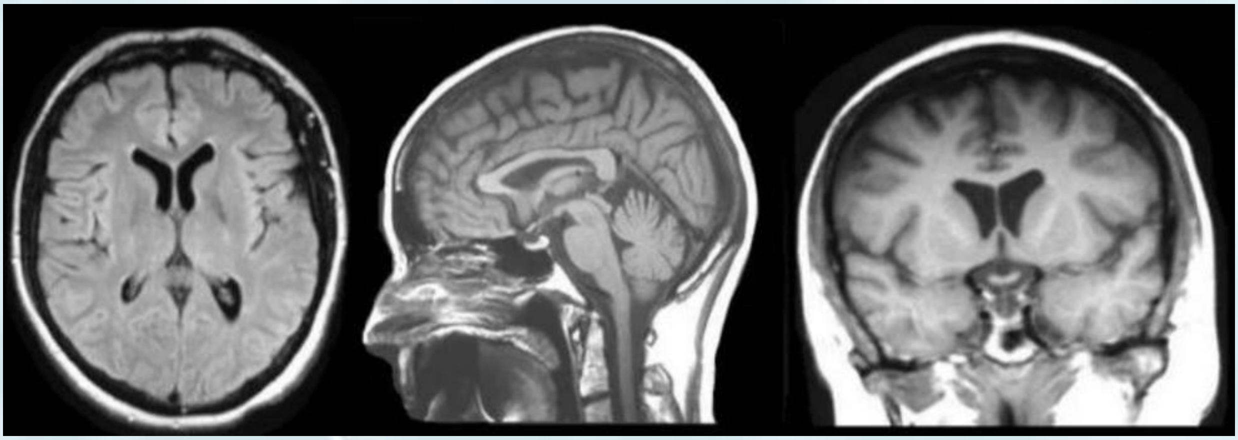


ST SEGMENT- All the cardiac cells in the ventricles have depolarized. Repolarization of cells in ventricle begins.

T WAVE- This is when the cells of the ventricle repolarize. During this stage, ventricles empty out and the semilunar valves close.

U WAVE- A normally small – peaked wave that follows the T wave. It is believed to be caused by the repolarization of cells found in the interventricular septum.

Magnetic Resonance Imaging



What is MRI?

Magnetic resonance imaging (MRI) is one of the most commonly used tests in neurology and neurosurgery. MRI provides exquisite detail of brain, spinal cord and vascular anatomy, and has the advantage of being able to visualize anatomy in all three planes: axial, sagittal and coronal (see the example image above).

MRIs employ powerful magnets which produce a strong magnetic field that forces protons in the body to align with that field. When a radiofrequency current is then pulsed through the patient, the protons are stimulated, and spin out of equilibrium, straining against the pull of the magnetic field.

How does it work?

MRI is based on the magnetization properties of atomic nuclei. A powerful, uniform, external magnetic field is employed to align the protons that are normally randomly oriented within the water nuclei of the tissue being examined. This alignment (or magnetization) is next perturbed or disrupted by introduction of an external Radio Frequency (RF) energy.

The nuclei return to their resting alignment through various relaxation processes and in so doing emit RF energy. After a certain period following the initial RF, the emitted signals are measured. Fourier transformation is used to convert the frequency information contained in the signal from each location in the imaged plane to corresponding intensity levels, which are then displayed as shades of gray in a matrix arrangement of pixels. By varying the sequence of RF pulses applied & collected, different types of images are created. Repetition Time (TR) is the amount of time between successive pulse sequences applied to the same slice. Time to Echo (TE) is the time between the delivery of the RF pulse and the receipt of the echo signal. MRIs employ powerful magnets which produce a strong magnetic field that forces protons in the body to align with that field. When a radiofrequency current is then pulsed through the patient, the protons are stimulated, and spin out of equilibrium, straining against the pull of the magnetic field.

Basic Principles

MRI scans work as an imaging method due to the unique make-up of the human body. We are comprised entirely of cells which all contain water – principally made of hydrogen ions (H_2O).

The magnet embedded within the MRI scanner can act on these positively charged hydrogen ions (H^+ ions) and cause them to 'spin' in an identical manner. By varying the strength and direction of this magnetic field, we can change the direction of 'spin' of the protons, enabling us to build layers of detail.

When the magnet is switched off, the protons will gradually return to their original state in a process known as precession. Fundamentally, the different tissue types within the body return at different rates and it is this that allows us to visualise and differentiate between the different tissues of the body.

To perform a study, the person is positioned within an MRI scanner that forms a strong magnetic field around the area to be imaged. First, energy from an oscillating magnetic field is temporarily applied to the patient at the appropriate resonance frequency.

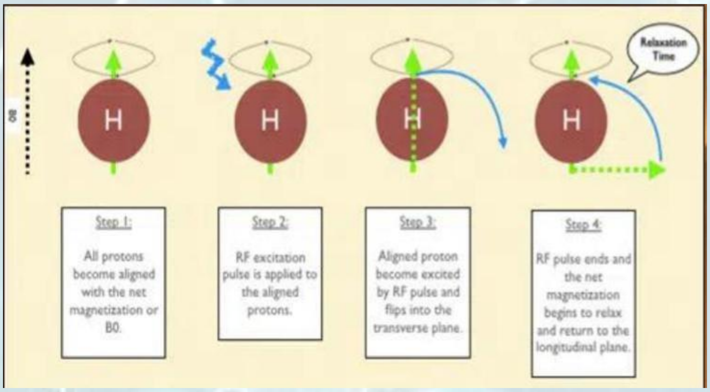
Scanning with X and Y gradient coils causes a selected region of the patient to experience the exact magnetic field required for the energy to be absorbed.

The atoms are excited by a RF pulse and the resultant signal is measured by a receiving coil. The RF signal may be processed to deduce position information by looking at the changes in RF level and phase caused by varying the local magnetic field using gradient coils.

As these coils are rapidly switched during the excitation and response to perform a moving line scan, they create the characteristic repetitive noise of an MRI scan as the windings move slightly due to magnetostriction. The contrast between different tissues is determined by the rate at which excited atoms return to the equilibrium state. Exogenousa contrast agentsmay be given to the person to make the image clearer.

The major components of an MRI scanner are the main magnet, which polarizes the sample, the shim coils for correcting shifts in the homogeneity of the main magnetic field, the gradient system which is used to localize the region to be scanned and the RF system, which excites the sample and detects the resulting NMR signal.

The whole system is controlled by one or more computers.



MRI requires a magnetic field that is both strong and uniform to a few parts per million across the scan volume. The field strength of the magnet is measured in Teslas – and while the majority of systems operate at 1.5 T, commercial systems are available between 0.2 and 7 T. Whole-body MRI systems for research applications operate in e.g. 9.4T, 10.5T 11.7T.

Even higher field whole-body MRI systems e.g. 14T and beyond are in conceptual proposal or in engineering design. Most clinical magnets are superconducting magnets, which require liquid helium to keep them at low temperatures.

Lower field strengths can be achieved with permanent magnets, which are often used in "open" MRI scanners for claustrophobic patients. Lower field strengths are also used in a portable MRI scanner approved by the FDA in 2020 Recently,

MRI has been demonstrated also at ultra-low fields, i.e., in the micro-Tesla to milli-Tesla range, where sufficient signal quality is made possible by prepolarization (on the order of 10–100 mT) and by measuring the Larmor precession fields at about 100 microtesla with highly sensitive superconducting quantum interference devices (SQUIDs).

In conclusion, MRI (Magnetic Resonance Imaging) is a cornerstone of modern medical physics, revolutionizing diagnostic imaging with its non-invasive, high-resolution capabilities. Its use continues to expand, driven by advancements in technology and understanding of physics principles. As we look ahead, further innovations in MRI promise even greater precision and clinical utility, reaffirming its critical role in healthcare and medical research.

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Hyperspace: Reel or Real?

Ankita Paul, Sem - IV

Interstellar travel, a staple of science fiction, often relies on the concept of hyperspace, a theoretical realm that allows for faster-than-light (FTL) travel.
This paper explores the scientific basis for hyperspace, examining theoretical models and the challenges associated with achieving FTL travel. It then dives into analysing hyperspace's portrayal in fiction and its impact on our understanding of space exploration. Furthermore, it enlightens us about the alternatives to FLT concepts, talks about the implications of spacetime manipulation and elaborates on how hyperspace and humanity is a cultural tapestry.

I. The Scientific Landscape of Hyperspace:

The concept of hyperspace arises from theoretical physics, particularly from attempts to reconcile the theory of relativity with the possibility of FTL travel. Einstein's special theory of relativity posits that the speed of light is the universal constant, an insurmountable barrier. However, theoretical models like wormholes and warp drives suggest potential loopholes.

Wormholes: These hypothetical tunnels connect two points in spacetime, essentially creating shortcuts between distant locations. The physics of wormholes is highly speculative, with significant challenges regarding their stability and potential dangers.

Warp drives: Proposed by Miguel Alcubierre, these theoretical engines would warp spacetime around a spacecraft, allowing it to travel faster than light without technically violating special relativity. However, the energy requirements for such a drive are currently thought to be immense, exceeding the capabilities of any known technology.

II. Challenges and Uncertainties:

Despite the theoretical models, achieving FTL travel in practice remains a significant hurdle. The main challenges include:

The nature of spacetime: Our understanding of the universe at the quantum level is incomplete. It's unclear if manipulating spacetime in the way proposed by FTL models is even possible.

The immense energy requirements: Both wormholes and warp drives require manipulating spacetime on a massive scale, potentially requiring energy exceeding what we can currently generate.

The unknown dangers: The potential consequences of manipulating spacetime are largely unknown and could pose unforeseen risks.

III. Hyperspace in Fiction and Culture:

While the scientific reality of hyperspace remains uncertain, it has captured the imagination for decades. From the iconic Millennium Falcon in Star Wars to the TARDIS in Doctor Who, hyperspace has become a cornerstone of science fiction, allowing stories to explore vast distances and imagine interstellar civilizations.

This fictional portrayal has influenced our cultural understanding of space exploration. By offering a plausible explanation for FTL travel, it fuels the human desire to explore the universe and encounter the unknown.

IV. Conclusion:

The existence of hyperspace remains firmly in the realm of scientific speculation. While theoretical models exist, the challenges of achieving FTL travel are immense, and the potential dangers are unknown. Nonetheless, hyperspace serves as a powerful tool for exploring the possibilities of space travel and fuels our curiosity about the vast universe beyond our reach.

V. Beyond the Wormhole: Alternative FTL Concepts:

While wormholes and warp drives are the most popular contenders for FTL travel, theoretical physicists continue to explore alternative avenues. Here are a few intriguing concepts:

Alcubierre Drive Variations: The original Alcubierre drive requires exotic matter with negative energy density, a substance yet to be observed. Modified versions explore alternative ways to warp spacetime, such as using Casimir cavities (the energy difference between empty and confined space) or manipulating vacuum energy.

Krasnikov Tubes: These theoretical structures are cosmic strings, incredibly thin and long objects with immense gravitational pull. If manipulated correctly, they could potentially connect distant points in spacetime, although their stability and safety are highly dubious.

Negative Mass Propulsion: This concept utilizes hypothetical particles with negative mass to create a propellant that could achieve faster-than-light speeds. However, the existence and behaviour of negative mass remain purely theoretical.

Quantum Mechanics Exploitation: Some proposals delve into the strangeness of quantum mechanics. Ideas like exploiting quantum entanglement or manipulating the probabilistic nature of particles for propulsion are explored, though significant theoretical hurdles remain.

VI. The Fabric of Reality: Implications of Spacetime Manipulation:

Manipulating spacetime on a large scale to achieve FTL travel would likely have profound consequences, some potentially beneficial, others highly dangerous:

Energy Consumption: The vast amount of energy required for warping spacetime could deplete entire galaxies or trigger unforeseen catastrophic consequences. Understanding energy requirements and potential side effects is crucial.

Spacetime Instability: Altering the fabric of spacetime could create unpredictable tears or distortions, potentially trapping spaceships or creating dangerous new realities. Ensuring manipulation is stable and controlled necessitates extreme caution.

New Physics Opportunities: The process of manipulating spacetime itself could lead to breakthroughs in our understanding of physics. Studying the effects on fundamental forces and particles might unveil entirely new scientific paradigms.

VII. Hyperspace and Humanity: A Cultural Tapestry:

The concept of hyperspace has significantly impacted various societies and disciplines:

Science Fiction: Hyperspace is a cornerstone of science fiction, allowing for interstellar travel, alien encounters, and exploring vast galactic civilizations. It fuels the human desire to explore the unknown and pushes the boundaries of storytelling.

Space Exploration: While a hypothetical tool now, the concept of hyperspace inspires ongoing research in propulsion technologies and theoretical physics. It pushes the boundaries of what we believe is possible in space travel.

Philosophy and Religion: Hyperspace raises questions about the nature of reality, the boundaries of our universe, and the possibility of parallel dimensions. It can spark philosophical and religious debates about our place in the cosmos.

By analysing the cultural impact of hyperspace across different societies, we can gain valuable insights into human curiosity, the desire to explore, and the search for meaning in the vastness of space.

These are just a few points to consider when exploring alternative FTL models, the implications of manipulating spacetime, and the cultural impact of hyperspace. As our understanding of physics evolves, these questions may lead to groundbreaking discoveries or remain captivating science fiction. But one thing is certain - the human fascination with the possibility of hyperspace continues to fuel our exploration of the universe.

VIII. The Future of Hyperspace : Reel or Real?

As the concept of hyperspace continues to captivate the scientific community and popular imagination, the question remains: will it become a reality or remain confined to the realm of science fiction?

This section explores the potential path forward, examining the technological, scientific, and ethical hurdles that must be overcome to make hyperspace travel a genuine possibility.

The future of hyperspace lies at the intersection of groundbreaking scientific discoveries and innovative engineering. Researchers are actively investigating the theoretical underpinnings of hyperspace, leveraging the principles of quantum mechanics and general relativity to devise practical solutions for achieving faster-than-light travel. However, the challenges are formidable, requiring advancements in areas such as energy generation, material science, and computational power.

Alongside the technical obstacles, the ethical implications of hyperspace technology must be carefully considered. The ability to traverse vast distances in a matter of moments raises concerns about the impact on society, the environment, and the balance of power on a global scale. Policymakers and ethicists will play a crucial role in shaping the responsible development and deployment of hyperspace capabilities.

Ultimately, the future of hyperspace remains uncertain, poised between the realms of science fiction and scientific reality. The path forward will be paved by visionary thinkers, dedicated researchers, and innovative engineers, who must collaborate to overcome the daunting challenges and realize the profound potential of this transformative technology.

Information Source : Hyperspace by Michio Kaku, Wikipedia, etc.
Picture Source : Internet

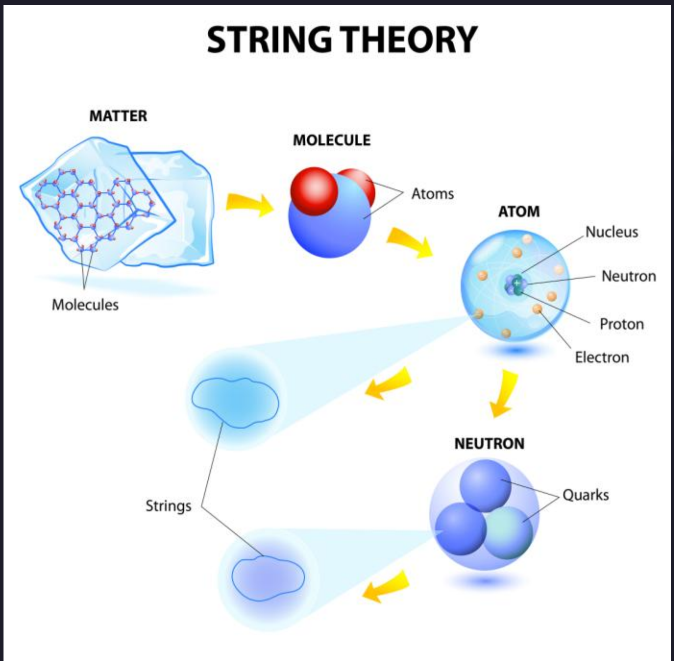
String Theory : The true nature of Everything

Dhriti Nath, Sem - IV

What is the true nature of the Universe ? To answer this question human come up with stories to describe the world. We test our stories and what to keep and what to throw away But the more we learn, the more complicated and weird our stories become. Like String Theory, famous controversial and often misunderstood story about the nature of everything . Is it correct ? To understand the true nature of everything we look close up to things . Everyone knows the story of Newton and an apple . Now let me ask you a question , what is inside the apple ?Let's magnify it . Sooner or later we will begin go see molecules come into view . But molecules are not the end of the story because molecules can be enlarged . If we make them big enough to see deep inside we began to see atoms , Atoms are not the end of the story too because we have electrons . Zooming around the nucleus mostly empty space in the atom but deep inside we see the nucleus . So if we grab that and magnify it we see that the nucleus is itself made of particles neutrons and protons . If we grab one of them and magnify it we find yet further particles little tiny quarks inside. Now that is the where the conventional idea stops . string theory comes along and suggest that inside this particles there is something else . So if we take a little quark and magnify it conventional idea says there is nothing inside but string theory says we find a little tiny filament . A little filament of energy , a little string like filament . And just like the string on a violin we pluck it and it vibrates , string in the string theory the don't produce musical note , they produce the particle themselves . A quark is nothing but a string vibrating in a pattern and electron is nothing but a string vibrating in different pattern . A neutrino is nothing but a string vibrating in a different patterns too . So we take all of this back together we have our ordinary apple. If these concepts are right deep inside the apple there are nothing but dancing vibrating cosmic symphony of strings.

Historical Background

The story begins in the 1960s when physicists were grappling with the fundamental forces of nature. Gabriele Veneziano's discovery of a mathematical formula, now known as the Veneziano amplitude, provided a promising approach to understanding the strong nuclear force. This model, though initially developed for hadron physics, laid the groundwork for what would become string theory . In the 1970s, the theory incorporated supersymmetry, which posits a symmetry between fermions and bosons. This led to the development of superstring theory, offering a unified description of gravity and the other fundamental forces. By the 1980s, five consistent superstring theories emerged, followed by the realization of dualities in the 1990s, suggesting these theories were different limits of a single underlying theory, known as M-theory. Despite its mathematical elegance and potential to unify physics, string theory faces challenges in experimental validation.



String theory proposes that the most basic constituents of the universe are not point particles, but rather one-dimensional "strings." These strings can vibrate at different frequencies, much like the strings on a musical instrument, and it is these different vibrational modes that give rise to the particles observed in nature. For instance, what we perceive as an electron, a quark, or a photon is actually a specific vibrational state of a string.

Vibrational Mode and Particle Spectrum

The idea that different particles are different vibrational modes of strings provides a natural explanation for the diversity of particles. In string theory, the mass and charge of a particle are determined by the way the string vibrates. There are numerous vibrational patterns possible, leading to a rich spectrum of particles, potentially including those beyond the Standard Model of particle physics.

Extra Dimension

String theory requires the existence of additional spatial dimensions beyond the familiar three dimensions of space and one of time. Specifically, most string theories are formulated in ten dimensions (nine spatial dimensions plus one time dimension), while M-theory is formulated in eleven dimensions (ten spatial plus one time). These extra dimensions are thought to be compactified or curled up into very small scales, typically on the order of the Planck length (~1.6×10^{-35} meters), making them difficult to detect with current technology.

Type of String Theories

There are five consistent superstring theories:

Type I : Involves both open and closed strings, and incorporates non-oriented strings.

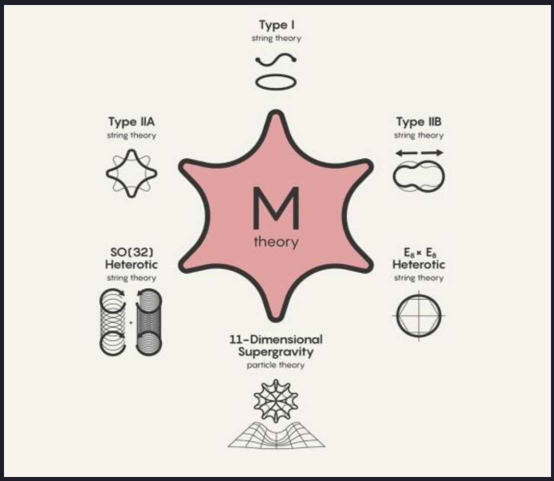
Type IIA and IIB : Both involve only closed strings, but differ in the nature of their super-symmetry (Type IIA is non-chiral, while Type IIB is chiral).

Heterotic SO(32) and Heterotic $E_8 \times E_8$: These involve a mix of closed strings, with one type of string having ten-dimensional supersymmetry and the other having 26-dimensional bosonic symmetry, compactified to ten dimensions.

Supersymmetry

Super-symmetry is a fundamental feature of string theory. It postulates a symmetry between fermions (matter particles like electrons and quarks) and bosons (force carrying particles like photons and gluons). Each particle has a super partner with differing spin. Supersymmetry aims to address several theoretical issues, such as the hierarchy problem, and predicts new particles that are yet to be observed experimentally.

M-Theory



M-theory emerged as a unifying theory that encompasses all five superstring theories. It is formulated in eleven dimensions and includes extended objects called branes (short for membranes), which generalize strings to higher dimensions (e.g., 2-branes or 3-branes). M-theory provides a broader framework within which the different string theories can be seen as different limits or approximations.

Dualities

Dualities are powerful symmetries in string theory that reveal deep connections between seemingly different theories. Some key dualities include:

T-Duality : Shows equivalence between theories with large and small compactified dimensions.

S-Duality : Relates theories with strong and weak coupling constants, suggesting that the strongly interacting regime of one theory corresponds to the weakly interacting regime of another.

U-Duality : A combination of T- and S-dualities, providing a comprehensive set of symmetries .

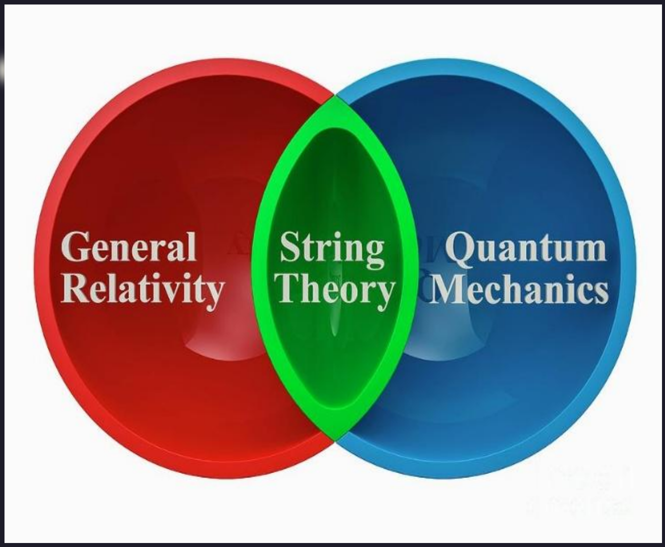
Quantum Mechanics and General Relativity

String theory aims to unify quantum mechanics and general relativity by proposing that the fundamental constituents of the universe are not point particles, but rather tiny, one dimensional strings. These strings can vibrate at different frequencies, and their vibrational modes correspond to the various particles observed in nature. Quantum mechanics describes the behavior of particles at the smallest scales, such as atoms and subatomic particles, incorporating the principles of uncertainty and superposition.

Additionally, when applied to extreme conditions, such as those near black holes or at the very beginning of the universe, the equations of general relativity break down and yield infinities, which are not physically meaningful.

String theory offers a potential resolution by replacing the point particles with strings, whose extended nature smoothes out the infinities that arise in point-particle theories.

General relativity, on the other hand, explains the gravitational interaction and the curvature of space-time caused by massive objects, effectively describing the universe at large scales.



The challenge in unifying these two theories arises because they operate under very different frameworks: quantum mechanics is fundamentally probabilistic, while general relativity is deterministic.

In string theory, gravity naturally emerges from one of the vibrational modes of the strings, providing a framework that inherently includes both quantum mechanics and a quantum theory of gravity. This means that string theory can describe gravitational interactions at quantum scales, where general relativity alone fails.

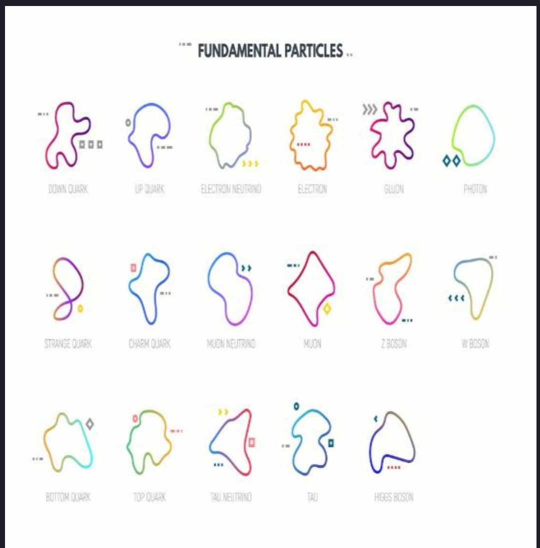
Moreover, string theory requires additional spatial dimensions beyond the familiar three, which can be compactified or hidden at scales too small to be detected with current technology. These extra dimensions allow for a richer structure in the theory, enabling the unification of all fundamental forces, including electromagnetism, the weak nuclear force, the strong nuclear force, and gravity. In summary, string theory aims to unify quantum mechanics and general relativity by introducing strings as the basic building blocks of the universe, smoothing out the problematic infinities and providing a consistent framework that includes a quantum description of gravity.

Implications and Application

String theory, by proposing that the fundamental elements of the universe are strings rather than point particles, has far-reaching implications for our understanding of the cosmos. One significant implication is the possibility of a multiverse. String theory's requirement of additional spatial dimensions leads to a variety of possible configurations for these dimensions, each corresponding to a different vacuum state with distinct physical properties. This suggests that our universe could be just one of many in a vast multiverse, each with its own set of physical laws and constants.

This multiverse concept alters our perspective on fundamental questions about the nature of reality and the uniqueness of our universe. It implies that what we observe might be just a small part of a much larger and more complex structure, where different regions of the multiverse could make entirely different forms of matter and energy, governed by different physical laws.

String theory also offers new insights into black holes. Traditional general relativity predicts singularities at the centre of black holes, where densities become infinite and the known laws of physics cease to apply. String theory, however, suggests that strings could replace the point-like singularities, providing a finite, well defined structure at the core of black holes.



This has led to the development of the holographic principle, which posits that all the information contained within a volume of space can be described by a theory that resides on the boundary of that space. This principle has profound implications for understanding the nature of space, time, and gravity.

Furthermore, string theory has provided a framework for studying black hole entropy and information paradoxes. It has offered models that account for the entropy of black holes in terms of the microstates of strings and branes, potentially resolving the paradoxes related to information loss in black holes.

Overall, string theory expands our understanding of the universe by introducing the concept of a multiverse and offering new ways to think about the fundamental nature of space, time, and black holes. These implications challenge and potentially revolutionize our comprehension of the cosmos and the laws that govern it.

In conclusion, String Theory is a fascinating and complex area of physics that holds tremendous promise for our understanding of the universe. While the theory faces a number of challenges and open questions, it also offers new insights and potential solutions to some of the most fundamental problems in physics. By proposing that the fundamental building blocks of the universe are tiny, one-dimensional strings vibrating in higher-dimensional space, String Theory offers a radically different perspective on the nature of reality. And while the theory may seem far-fetched or even unprovable to some, it remains an active area of research and study for physicists around the world. Whether String Theory ultimately proves to be correct or not, it represents an important step forward in our ongoing quest to understand the nature of the universe. By challenging our assumptions and expanding our thinking, String Theory reminds us of the power and beauty of science – and of the limitless potential of the human mind to explore the mysteries of the universe.

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Our Universe : The Mysterious Mystery

Barnali Das, Sem - II

HAVE WE EVER THOUGHT WHY OUR UNIVERSE IS BLACK? BECAUSE THERE IS NO ATMOSPHERE TO SCATTER LIGHT

Whenever we think about the universe firstly we can imagine a great blank space of mystery which includes galaxies, stars, planets. But actually we got to know only 5% about it and the 95% of this is invisible which are the enigmatic dark matter and dark energy. The density of dark energy is very low much less than the density of ordinary matter or dark matter. This dark energy is actually causing the universe to expand.

Dark energy

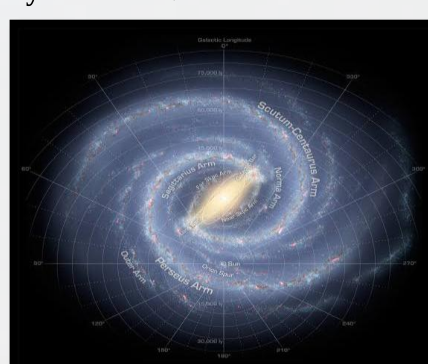
There are two trillion galaxies in this universe. The galaxies large in size like our galaxy or larger than that contain supermassive black hole at their centers. Dwarf galaxies do not contain any supermassive black hole at their center.

Black holes are created when massive stars collapse at the end of their life. These mysterious black holes are a place in the space where gravity pulls so much that even light cannot get out.

If one was to stand just outside the event horizon of this black hole and stand there for one minute, 700 years would pass because time passed so slower in the gravitational field there than it does on earth. The black hole named "Sagittarius A*" is near the center of our Milky Way Galaxy.

Sagittarius A*

This 13.6 billion years old barred spiral type Galaxy which was discovered by Galileo Galilee is called Milky Way because it appears as a milky band of light in the sky when one sees it in a really dark area.



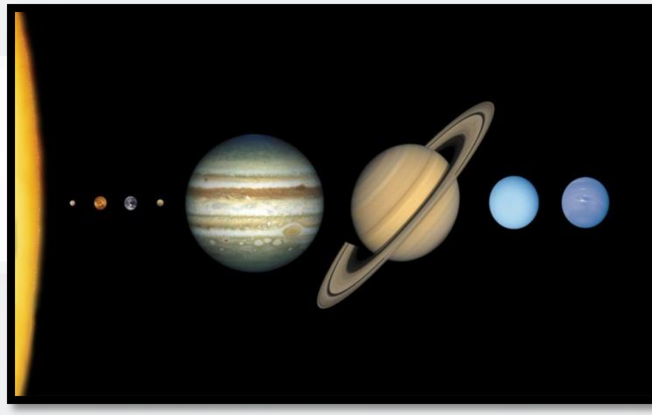
Milky Way Galaxy

Our Galaxy contains 100-400 billion stars. Our Sun is one of them which is a huge ball of Hydrogen and Helium held together by its own gravity. It is a medium sized star with a diameter of about 1.39 million kilometers and surface temperature of 5600° Celsius .
Proxima Centaury is the nearest star which is a small , low mass star it is approximately 4.24 light years away from the Sun . The black hole "Sagittarius A*" of our Galaxy is 26000 light years away from the Sun . The closest black hole to Earth is " Gaia-BH1 " which is 1560 light years away . This hole has a mass around 9.6 times that of the Sun.

Gaia-BH1

Our solar system is moving around the supermassive black hole situated at the galactic center of our Galaxy with an average velocity of 450000 miles per hour[720000 kilometers per hour]. There are eight planets and total five dwarf planets. The dwarf planet Ceres is situated in the main asteroid belt whereas rest four named Pluto, Makemake, Haumea and Eris are situated in Kuiper belt of our solar system. The eight different planets of our solar system have different characteristics. Mercury has a rough surface and have no natural satellite and ring though it is the closest planet of the Sun, the hottest planet is Venus which has a similar structure and size to Earth but the surface condition on Venus is extreme so sometimes it is called " Earth's evil twin ".

Movement of the Solar System



Solar System

The fourth planet of the solar system is Mars which is a dry , Rocky and bitter cold planet . Where Jupiter is the biggest planet and it has 95 satellites . Saturn has also 146 satellites and it has beautiful rings. Though Neptune is the most distant planet of sun, Uranus is the coldest planet. Those planets where diamond rain occurs are also Uranus and Neptune . The only planet of the solar system which is moving around the Sun with it's only natural satellite Moon, where life has been proven to exist is the Earth. The blue planet , our Earth is the address of us in the universe.

Now can you say surely that in this universe which is containing 2 trillion Galaxies and each galaxy containing more or less than 100 - 400 million stars and those stars which have more or less planets in their solar system have not a single planet without the Earth where life exists !!! Is it possible !!!

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Quantum Mechanics

Farriyah Arshi, Sem - II

Quantum mechanics is a fundamental theory in physics that describes the behavior of nature at and below the scale of atoms. It is the foundation of all quantum physics, which includes quantum chemistry, quantum field theory, quantum technology and quantum information science. Quantum mechanics can describe many systems that classical physics cannot. Classical physics can describe many aspects of nature at an ordinary macroscopic scale, but is not sufficient for describing them at atomic and sub atomic scales.

Quantum system have bound states that are quantized to discrete values of energy, momentum, angular momentum, and other quantities, in contrast to classical systems where these quantities can be measured continuously. Measurements of quantum systems show characteristics of both particles and wave nature(wave- particle duality), and there are limits to how accurately the value of a physical quantity can be predicated prior to its measurements subject to a complete set of initial conditions (the uncertainty principle).

Quantum estimation theory is a reformulation of random statistical theory with the modern language of quantum mechanics. In fact, the density operator plays a role similar to that of probability distribution functions in the classical probability theory and statistics. However, the use of probability distribution function in classical theories is founded on premises that seen intuitively clear enough.

The case of classical physics, a choice must be made, because in quantum mechanics not everything can be measured. As Werner Heisenberg realized a particle cannot have, at the same time, both a definite position and a definite velocity. Quantum mechanics is one of the most successful theories in all of physics.

The quantum effects of physics are at the atomic and sub atomic level, brought to us courtesy of quantum mechanics, and hold the key to major advances- quantum leaps in communication, measurement, and sensing, know collectively as quantum information science. Quantum mechanics has literally transformed the future of electronic devices (such as transistors, diodes etc) and enable their integration into a variety of household application as well as in industry.

To conclude one can say that Quantum Mechanics plays a crucial role in modern science though it can not be the answer to all problems of Physics..

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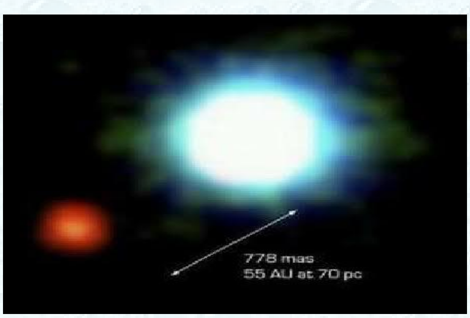
Discovering New Worlds: The Exciting Hunt for Exoplanets

Sharqa Tarneem Faique, Sem - II

Imagine looking up at the night sky and wondering if there are other worlds out there, just like Earth. This fascinating question has intrigued humans for centuries. Recently, scientists have begun to find answers by discovering exoplanets—planets that orbit stars outside our solar system. These discoveries aren't just about finding new planets; they're about finding places that might even support life.

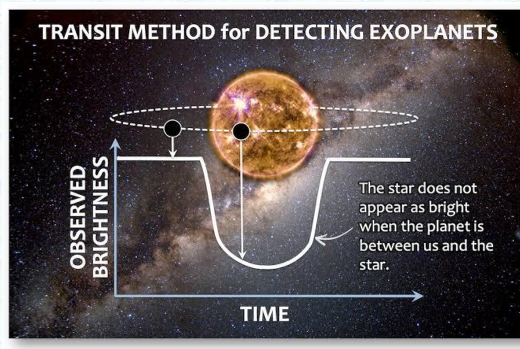
Exoplanets are planets that orbit stars other than our Sun. They come in all shapes and sizes, from giant gas planets bigger than Jupiter to rocky planets smaller than Earth. Some exoplanets orbit close to their stars and are incredibly hot, while others are far away and freezing cold. The diversity of these planets is astonishing.

But the real question that keeps scientists up at night is: could there be life on these distant worlds? Just like in sci-fi movies, we wonder if there are beings looking up at their sky, wondering about us. It's a mystery waiting to be solved.

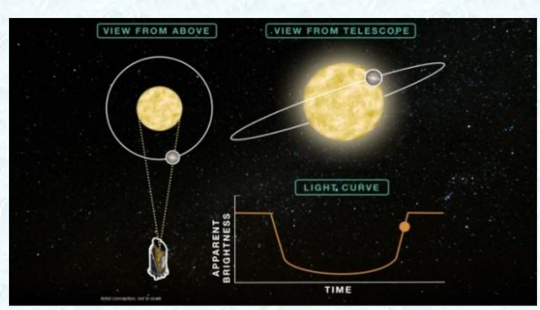


Direct Image Method:-This picture shows the first direct image of an exoplanet

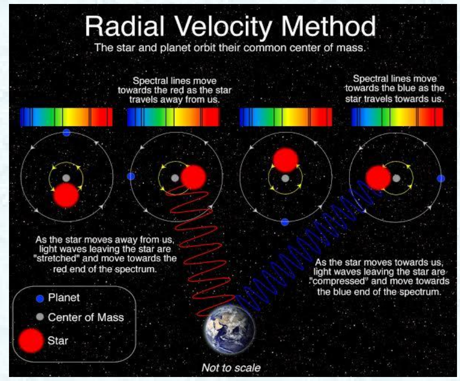
Finding exoplanets is like detective work. Scientists use powerful telescopes and clever techniques to spot these distant worlds.



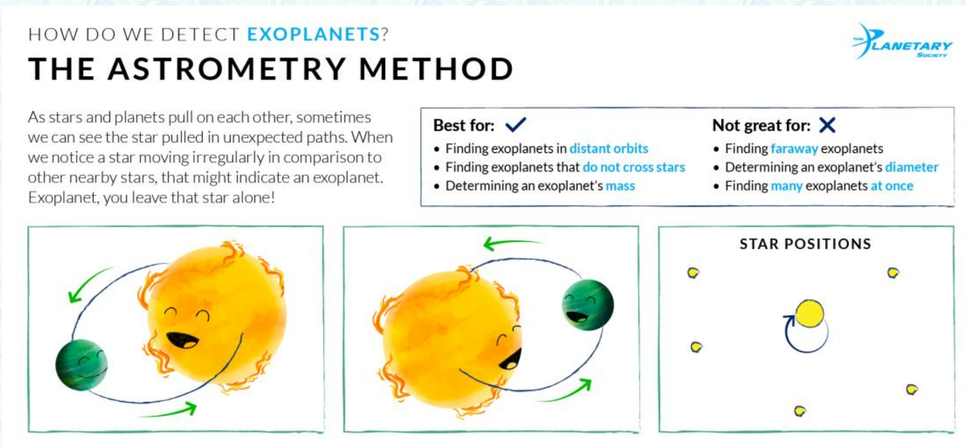
One common method is the transit method. This is when a planet passes in front of its star, causing a tiny dip in the star's brightness. By carefully measuring these dips, scientists can tell if a planet is there, how big it is, and how far it is from its star.

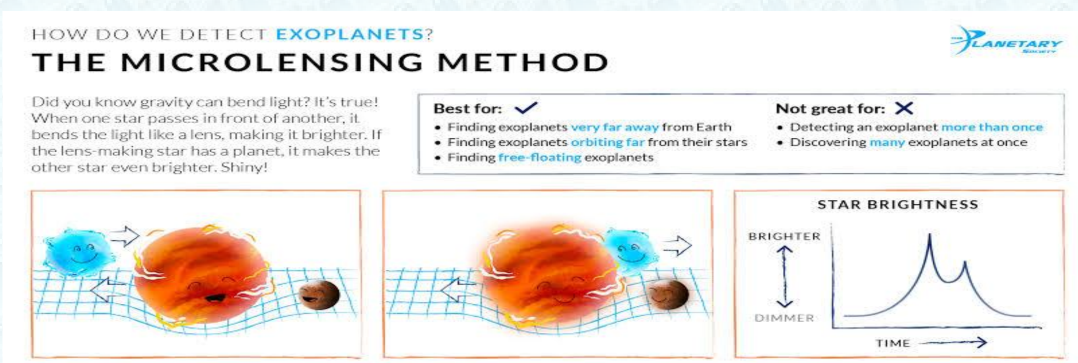


Another method is the radial velocity method. This technique looks for the tiny wobbles in a star's motion caused by the gravitational pull of an orbiting planet. By studying these wobbles, scientists can infer the presence of a planet and estimate its mass. It's amazing how these small movements can reveal so much about planets light-years away.

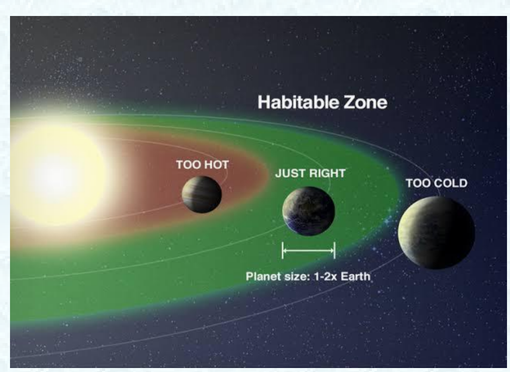


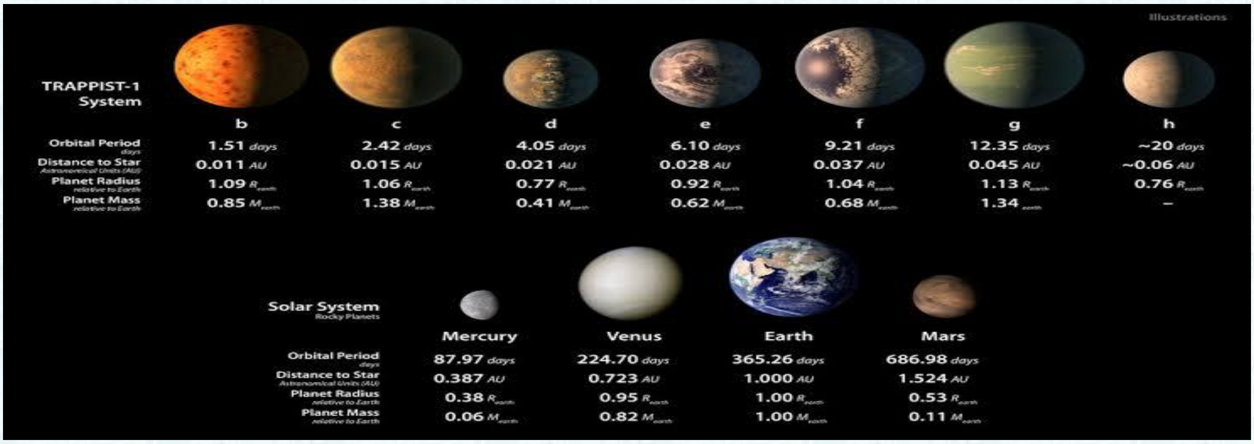
Graphical Representation of other important methods of finding Exoplanets





Exoplanets are crucial because they help us understand more about our universe. They teach us how planets form and evolve. Most excitingly, some exoplanets are in the "Goldilocks zone"—a region around a star where conditions might be right for liquid water, essential for life as we know it.





Trappist 1:-Static Table

Discovering such planets brings us one step closer to answering the age-old question: Are we alone in the universe?

One of the most thrilling discoveries is the TRAPPIST-1 system, which has seven Earth-sized planets orbiting a cool star. Three of these planets are in the habitable zone. Imagine the possibilities—these planets could have the right conditions for life!

Proxima Centauri b

Another fascinating discovery is Proxima Centauri b, the closest known exoplanet to Earth, just 4.2 light-years away. This planet orbits its star in the habitable zone, making it an exciting target for future missions.

The hunt for exoplanets is one of the most exciting adventures in modern science. Each new discovery is a step closer to finding a world like our own, or even discovering life beyond Earth. As we continue to explore the cosmos, who knows what incredible worlds we will find next?
Every new exoplanet discovery brings us closer to understanding the vastness of the universe and our place in it. It's like finding a new piece to a never ending puzzle . Each planet has its own story to tell , its own secret to reveal.
So, next time you look up at the stars, remember that out there, in the vastness of space, there are countless exoplanets waiting to be discovered, each with its own story to tell. The universe is a big place, and we're just beginning to explore it.

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Folklores From Physics

Shweta Mukherjee, Sem - II

" Curiouser and curiouser.. ", utters the world of physics. From the majestic supernovas to the tiny particles, physics unravels the mystery of everything. The world of physics and by extension science holds stories filled with curiosity, patience, determination, love, happy and sad accidents, passion, heartbreaks and humour. Let us peep into a few of those tales today.

1) The Man Who Envisioned The Future

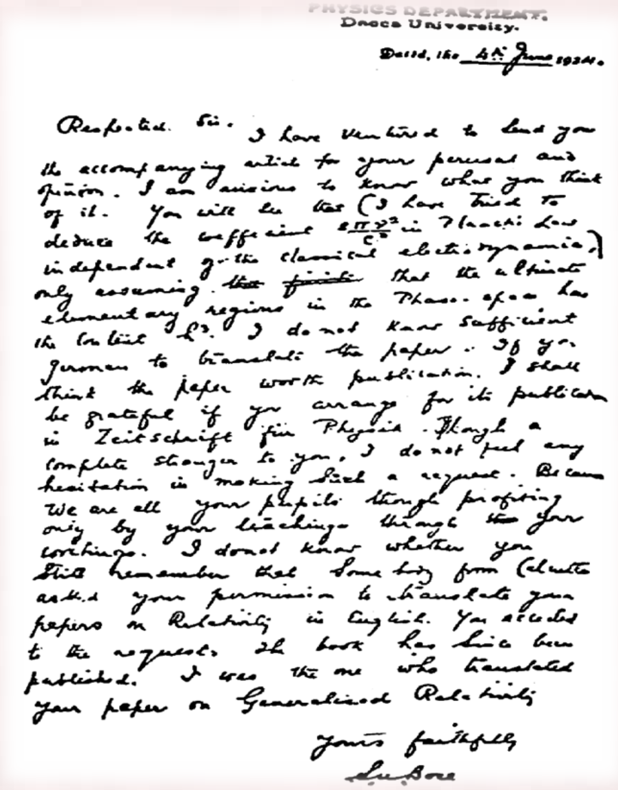
1924, Curzon Hall, University Of Dacca. A young gentleman wrote a paper titled 'Plank's Law and the Hypothesis of Light Quanta'. He sent it to the journal 'Philosophical Magazine', but they rejected it stating the paper was incorrect. Then the man wrote a letter to Albert Einstein and attached the paper to it. Einstein studied the paper and understood its importance as he also worked on the same problem once but couldn't reach any solution. He translated it to German and the paper was published in the journal Zeitschrift für Physik.

Satyendra Nath Bose

About the paper Einstein mentioned "I liked it very much. … It is a beautiful step forward!" The man was Acharya Satyendra Nath Bose, who paved a new way in the world of quantum physics. Einstein also said to his friend Paul Ehrenfest "The Indian Bose has given a beautiful derivation of Planck's law including the constant $8\pi v^2/c^3$."

S.N. Bose developed a new method of calculation called "Bose Statistics" which was furthermore developed by Albert Einstein and now known as "Bose-Einstein Statistics". The particles whose nature can be described through 'Bose-Einstein Statistics' are known as Bosons. Years later, in 2012, the scientists working in CERN, Switzerland, discovered the God Particle, a Boson which is also known as the Higgs-Boson particle. All the matter of this universe gained mass because of the interaction between Higgs field and Higgs-Boson particle.

Einstein also published another paper of S.N Bose in German, but as a footnote to that second paper, he added that the new calculation (which was not "Bose Statistics") proposed by Bose was wrong.



PHYSICS DEPARTMENT.
Dacca University.

Dated, the 4th June 1924.

Respected Sir,

I have ventured to send you the accompanying article for your perusal and opinion. I am anxious to know what you think of it. You will see that (I have tried to deduce the coefficient $\frac{8\pi\nu^2}{c^3}$ in Planck's Law independent of the classical electrodynamics) only assuming ~~the finite~~ that the ultimate elementary regions in the Phase-space has the content h^3. I do not know sufficient German to translate the paper. If you think the paper worth publication, I shall be grateful if you arrange for its publication in Zeitschrift für Physik. Though a complete stranger to you, I do not feel any hesitation in making such a request. Because we are all your pupils though profiting only by your teachings through your writings. I do not know whether you still remember that somebody from Calcutta asked your permission to translate your papers on Relativity in English. You acceded to the request. The book has since been published. I was the one who translated your paper on Generalised Relativity.

Yours faithfully
S.N. Bose

Bose's Letter to Albert Einstein

But he didn't tell Bose about the footnote. But many years later S.N Bose told his student Partha Ghose "my deduction of the Planck law had a factor of 2 missing. So I proposed that it came from the fact that the photon had a spin, and that it can spin either parallel or antiparallel to its direction of motion. That would give the additional factor of 2. But the old man [meaning Einstein] crossed it out and said it was not necessary to talk about spin, the factor of 2 comes from the two states of polarization of light. I can understand a spinning particle, but what is the meaning of the polarization of a particle?" Ghose asked him that, "Sir, when photon spin was eventually discovered, why didn't you tell Einstein that you had discovered it already in 1924?

No doubt a person like Einstein would have stood by you and you would have surely won a Nobel Prize!"

But S.N Bose replied, "How does it matter who discovered it? It has been discovered, hasn't it !"

During the Banga-bhanga Andolan, Satyendranath Bose helped the rebels. He also used to teach in night schools. He was a great science enthusiast. Rabindranath Tagore dedicated his book "Bishwa-Parichay" to Satyendra Nath Bose. The man worked with limited facilities, limited technologies and a mind full of unlimited potential. Yet he envisioned something that is revolutionary. His discovery led to many discoveries in physics. A student once asked their physics professor who was Bose. The professor replied, " You don't know who he was? Half the particles in the universe obey him."

S.N Bose playing 'Esraj

2) Tale of the Infant Universe

The universe began with a rapid inflation and expansion and then it began to cool down. This is the Big Bang Theory. When the universe started to cool off, the formation of matter began and photons started travelling freely. The remnant of the first light that travelled freely and apparently is found in every space of the universe is known as the Cosmic Microwave Background.

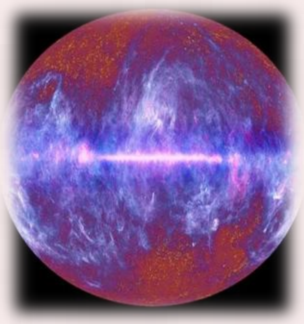


Image of the CMB radiation collected by European Space Agency's Planck satellite

In July, 1965, two scientists Arno Penzias and Robert Wilson were working with a radio telescope in Bell Labs, New Jersey. They detected a strange 'noise' in their radio telescope, which was apparently coming from everywhere, all day, everyday.

The Horn Antenna of the Bell Labs, NJ

Arno Penzias and Robert Wilson

They tried to find the source of the noise but they couldn't detect properly. Then they thought the noise was generating either due to bad wirings or the large amount of pigeon excreta. They fixed both, yet that noise signal in the microwave range continued to appear. Meanwhile, around the same time physicist Robert H. Dicke theorized that if the universe was born due to the Big Bang, there would be a faint background radiation of 3° K present all throughout the universe. He visited the Bell Labs and confirmed the mysterious signal to be the "shockwave" from the Big Bang. Hence the cosmic microwave background was discovered and the proof of the Big Bang was supported. Pretty cool, ain't *it?*

Robert H. Dicke

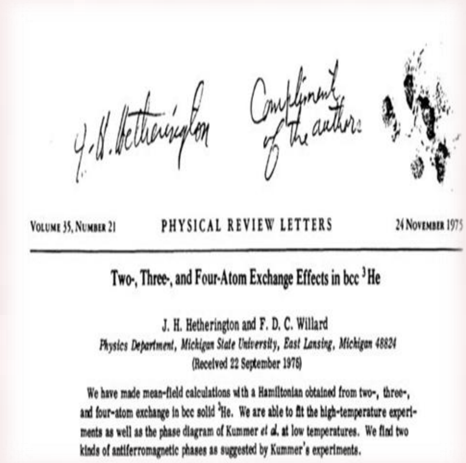
3) The curious case of Mr. F.D.C. Willard

The date was 24th November, 1975. In the 35th edition of the journal "Physical Review Letters", a paper published, titled "Two- Three- Four- Atom Exchange Effects in bcc ^3He", co-authored by Professor J.H. Hetherington, a physicist and mathematician of Michigan State University in the United States and some Mr. F.D.C Willard. Afterwards Prof. Hetherington sent signed copies of the paper to some of his friends and colleagues. However, the signature of the mysterious Mr. Willard appeared to look like an inked "paw-print" and soon to quote Prof. Hetherington, "the cat was out of the bag." It became widely known that F.D.C Willard was actually a cat. The case is, the aforesaid paper was solely written by professor Hetherington himself, but throughout the whole paper he used "we" and "our" instead of the first person singular pronoun "I". When he sent the paper to one of his colleagues to review the paper before publication, the colleague pointed out this mistake and a problem arose as "Physical Review Letters" had a rule that only first person singular pronouns were to be used in a paper written by only one author. To fix the mistake meant he had to re-type the entire paper again in his type writer. To save himself from this tedious job, he came up with a smart solution. He added a name as a co-author of the paper but that name was actually his pet cat's name. Hetherington had a Siamese cat named Chester and to make it sound like a more human name he added some other elements to the name and came up with the name F.D.C. Willard. F and D are actually the initials of the scientific name of the house cat *"Felis domesticus"*, C stands for Chester and Willard was the name of the cat's father. Chester was whole-heartedly accepted by much of the scientific world and he was even offered a post in the physics department of Michigan State University,

A picture of Chester a.k.a F.D.C Willard

however it is not known whether he ever cared to pay attention to that request.

In 1980, Mr. Willard appeared to had solely author a paper titled "Solid helium 3: a nuclear antiferromagnetic element" entirely in French and in a French journal called "La Recherche". Even though the legendary cat passed away at the age of fourteen in 1982, his legends still live. In the honour of F.D.C. Willard, American Physical Society quoted, *"Not since Schrödinger has there been an opportunity like this for cats in physics."* Science for all and all for science



J.H. Hetherington   Compliments of the authors

VOLUME 35, NUMBER 21   PHYSICAL REVIEW LETTERS   24 NOVEMBER 1975

Two-, Three-, and Four-Atom Exchange Effects in bcc ^3He

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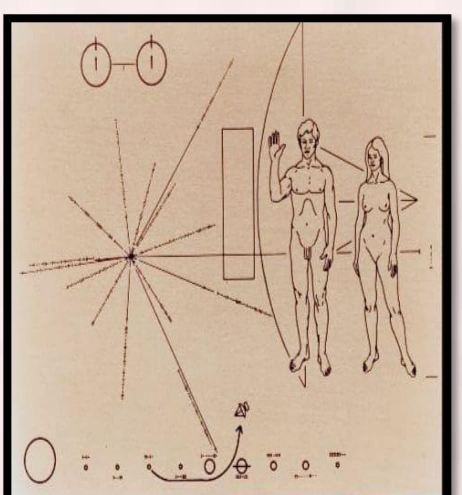
(Received 22 September 1975)

We have made mean-field calculations with a Hamiltonian obtained from two-, three-, and four-atom exchange in bcc solid ^3He. We are able to fit the high-temperature experiments as well as the phase diagram of Kummer *et al.* at low temperatures. We find two kinds of antiferromagnetic phases as suggested by Kummer's experiments.

The signed paper

4) We Have A Message To Deliver

Since the time we gained the consciousness that we live in an infinitesimally small space in this ever expanding vast universe, we questioned ourselves whether we are alone here. We have tried to find the answer to it, we still do. Like the Pioneer Plaques. Pioneer Plaques are two identical gold plated plaques attached to the exteriors of Pioneer 10 and Pioneer 11 spacecrafts. The plaques contain coded messages in the form of pictures from the Earthians to their cosmic neighbours. Pioneer 10 was designed to study the environment of Jupiter, asteroids and solar winds. Pioneer 11 was designed to observe Jupiter and Saturn in detail. It was calculated that after a certain time both the spacecrafts would have gained enough velocity to cross our solar system and carry their voyages to different destinations, forever. Dr. Carl Sagan, an astronomer suggested the idea of the plaque. The idea behind the plaques were, if the Pioneers ever come across any extraterrestrial form of life during their never ending voyages, they would deliver some messages to them from a planet called Earth, who also sustains life maybe in a similar or a different way.



The Pioneer Plaque

Both the plaques begin with the picture of the atom of Hydrogen, an element which is found all across our universe; There are pictures of a man and a woman, position of our sun in the Milky Way galaxy and the plan of the solar system with the flight path of the Pioneer. All the sketches are mathematically and finely designed. Artist Linda Salzman Sagan and astrophysicist Dr. Frank Drake sketched the designs of the plaques. "It will be the oldest artifact of mankind…A billion years from now, mountain building and erosion will have destroyed everything on the Earth, but this plaque will remain intact."- quoted Dr. Sagan.

Dr. Carl Sagan and Linda Salzman

Dr. Frank Drake

Pioneer 11 is currently in the constellation Scutum and Pioneer 10 is in the constellation Taurus. We really don't know till now whether we'll ever receive any knock from the other side. We take up such an infinitesimally small place in this universe.

We have started from the great emptiness and reached so far, will walk further. Different galaxies, stars, moons, planets, environments and lives yet we all are connected through our vast, mysterious universe.

“আকাশভরা সূর্য-তারা, বিশ্বভরা প্রাণ
তাহারি মাঝখানে আমি পেয়েছি মোর স্থান,
বিস্ময়ে তাই জাগে আমার গান॥
অসীম কালের যে হিল্লোলে জোয়ার-ভাঁটার ভুবন দোলে
নাড়ীতে মোর রক্তধারায় লেগেছে তার টান,
বিস্ময়ে তাই জাগে আমার গান॥”

[Translation: My heart sings at the wonder of my place
In this world of light and life;
At the feel in my pulse of the rhythm of creation
Cadenced by the swing of the endless time.]

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