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KPA NEWSLETTER – 9 **NOVEMBER 2025**

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Contents

Editorial

This year's Nobel Prize in physics was announced on October 7, 2025. Three scientists – John Clarke, Michel H. Devoret and John M. Martinis have been jointly awarded the prize for 'the discovery of macroscopic quantum mechanical tunnelling and energy quantisation in an electric circuit.'

A brief description of their contribution can be obtained from the first article.

The importance and necessity of encouraging curiosity in Indian students is discussed in the next article by a well-known educationist.

A clear account of the revolutionary contribution of S N Bose in understanding the nature of black body radiation can be found in the next article. It is said to be the first purely quantum mechanical treatment of photons.

An account of the amazing contributions of Albert Einstein in the year 1905 – called the Annus Mirabalis - can be found in the next article.

The speed of light in vacuum is believed to be the limiting of speed for all particles. The next article explains the consequences of such a limit in mechanics with numerical examples.

It is interesting and educational to learn about the twists and turns behind the discovery of various objects and explanations in physics. The next article tells us the major steps leading to the discovery of neutron stars.

The next article describes the recent breakthroughs in arriving at the quantum theory of damped harmonic oscillator while the simple harmonic oscillator was one of the earliest applications of quantum mechanics.

A biographical sketch of Philipp Lenard – called a 'Nazi physicist'- can be found in the next article.

The next article is all about astrology – asking the perennial question: is it a science? Fascination with it continues even today worldwide in all sections of the society.

Anecdotes about scientists make amusing reading for all, showing the strange behaviors of, apparently, highly intelligent human beings in society. The next article gives a dose of such anecdotes for all to enjoy.

The next article gives an account of the recent discovery of astronomers that comets can transport water in space from distant regions – raising speculations about the origin of water on Earth.

An article in Kannada about the interesting facts about the planet Uranus appears next.

An interesting and informative article about the new field of biophotonics can be found next.

A brief account of the activities of KPA members, along with a few photographs during the period: 1-9-2025 to 31 -10-2025 can be found next.

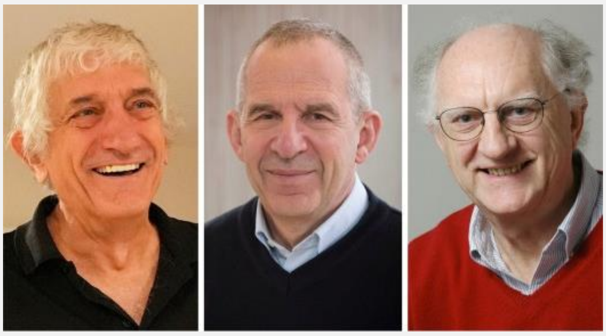
Finally, a list of webinars held during the above mentioned period is also noted.

KPA wishes to thank Dr.Muktha B. Kagali for designing the newsletter at a short notice, without charge!

We would be pleased to receive your feedback on the articles in this issue. We appeal to all KPA members as well as others to contribute interesting articles to the next issue of the newsletter.

Chief Editor

The Nobel Prize in Physics 2025:
Their experiments on a chip revealed quantum physics in action



John M. Martinis   Michel H. Devoret   John Clarke

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics in 2025 to John Clarke, University of California, Berkeley, USA, Michel H. Devoret, Yale University, New Haven, CT and University of California, Santa Barbara, USA, and John M. Martinis, University of California, Santa Barbara and Qolab, Los Angeles, CA, USA,

"For the discovery of macroscopic quantum mechanical tunnelling and energy quantisation in an electric circuit"

A major question in physics is the maximum size of a system that can demonstrate quantum mechanical effects. This year's Nobel Prize Laureates conducted experiments with an electrical circuit in which they demonstrated both quantum mechanical tunnelling and quantised energy levels in a system big enough to be held in the hand.

Quantum mechanics allows a particle to move straight through a barrier, using a process called tunnelling. As soon as large numbers of particles are involved, quantum mechanical effects usually become insignificant. The laureates' experiments demonstrated that quantum mechanical properties can be made concrete on a macroscopic scale.

In 1984 and 1985, **John Clarke**, **Michel H. Devoret** and **John M. Martinis** conducted a series of experiments with an electronic circuit built of superconductors, components that can conduct a current with no electrical resistance. In the circuit, the superconducting components were separated by a thin layer of non-conductive material, a setup known as a Josephson junction. By refining and measuring all the various properties of their circuit, they were able to control and explore the phenomena that arose when they passed a current through it. Together, the charged particles moving through the superconductor comprised a system that behaved as if they were a single particle that filled the entire circuit.

This macroscopic particle-like system is initially in a state in which current flows without any voltage. The system is trapped in this state, as if behind a barrier that it cannot cross. In the experiment the system shows its quantum character by managing to escape the zero-voltage state through tunnelling. The system's changed state is detected through the appearance of a voltage.

The laureates could also demonstrate that the system behaves in the manner predicted by quantum mechanics – it is quantised, meaning that it only absorbs or emits specific amounts of energy.

"It is wonderful to be able to celebrate the way that century-old quantum mechanics continually offers new surprises. It is also enormously useful, as quantum mechanics is the foundation of all digital technology," says Olle Eriksson, Chair of the Nobel Committee for Physics. The transistors in computer microchips are one example of the established quantum technology that surrounds us. This year's Nobel Prize in Physics has provided opportunities for developing the next generation of quantum technology, including quantum cryptography, quantum computers, and quantum sensors.

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Why India Needs to Encourage Curiosity - the Lifeline of Innovation, to Improve Its Nobel Score

For India to compete globally, curiosity must not be stifled but encouraged and this requires educational reforms.

Every year, as October arrives, the announcement of Nobel Prizes in science, literature, peace, and economics becomes big news worldwide. Since 1901, the Nobel Prize has honoured innovations that benefit humanity. True to the vision of Swedish chemist Alfred Nobel, who established the prize, the Nobel Foundation has recognised works and research primarily driven by curiosity, creativity, and originality.

According to the Indian Constitution, cultivating a scientific temper is a fundamental duty of every citizen, introduced through Article 51A (h) in the 42nd Amendment of 1976. This provision calls upon every citizen to develop a questioning attitude, humanism, and a spirit of reform. In essence, it encourages rationality, open-mindedness, and evidence-based thinking over superstition and blind acceptance. It reminds us that the ultimate goal of scientific advancement is human welfare.

Yet, despite being the most populous nation with a large number of scientists, creative writers, and economists, India has won only nine Nobel Prizes so far. In contrast, the United States of America has won over 400, while the United Kingdom, Germany, and France each have more than a hundred. Even a small country like Sweden has produced 35 Nobel laureates. In a way, Nobel counts are also indicators of national development. If India truly aims to become a developed nation by 2047, this indicator must also be taken seriously. The core issue is that we have not nurtured curiosity and creativity effectively among our children and students.

Stanford List – Celebration without Impact

The number of Indian scientists appearing in Stanford University's "Top 2% Scientists" list, prepared with Elsevier's collaboration, is steadily rising. In 2024, nearly 5,300 Indian scientists featured on it, which is indeed a matter of pride. Yet, despite this large pool of scientists, India has not produced Nobel-level breakthroughs in science in recent decades.

If so, many Indians appear in such rankings, it means research activity is happening at scale. But true scientific glory is not measured by the number of papers published. It is measured by creativity, originality, and benefit to society. Take for example the mRNA research that enabled COVID-19 vaccines, or the early foundational research in Artificial Intelligence (AI). Both were the results of decades of painstaking curiosity-driven work. These scientists were searching for answers to "why?"— not chasing awards.

A Problem of Our Own Making

Children are naturally curious; they constantly ask "Why?" If nurtured, this curiosity leads to discoveries and innovations. It also unlocks creativity. Unfortunately, our education system weakens this natural trait. Questioning is undervalued. Asking "Why?" is often seen as disruptive. Arguments are discouraged. Children are taught that accepting things as they are is a sign of maturity.

As a result, originality in research has substantially declined. The focus has shifted to producing more publications, earning higher citations, and filing patents—while truly new ideas get less recognition. This has turned India into a country of skilled professionals, but not of innovators who make world-changing breakthroughs.

Fostering a Culture of Curiosity

Curiosity is not just a natural instinct—it is a cultivated discipline. It leads people to ask meaningful questions and think from new perspectives. Many Nobel-winning discoveries were entirely unexpected, born from fresh ways of seeing problems. Curiosity breeds creativity, courage, and lifelong learning. Across disciplines—science, literature, arts, technology—human progress has always been curiosity-driven.

For India to compete globally, curiosity must not be stifled but encouraged. This requires educational reforms. Rote learning must give way to question-based learning. Novelty in research should be rewarded. Funding and recognition must go not only to the quantity of output but also to creative ideas. Policies must support risk-taking in research. Even if results take time, investment in basic research is essential. Society's attitude must shift—children's curiosity should be valued, not treated as an obstacle. Global collaborations must increase. India should not just add numbers but contribute ideas that change the world.

The Goal Ahead

The shortage of Nobel Prizes for India is not merely due to a lack of funds or infrastructure. The deeper cultural problem is our failure to nurture curiosity. No matter how much we expand institutions or facilities, they will not yield global recognition if they fail to empower students to ask "Why?". Curiosity is not a luxury—it is the foundation of innovation.

If India truly wants to stand on the world stage with transformative innovations, curiosity must be protected, encouraged, and honoured from childhood through every stage of life. Only then will we move from counting research papers and patents to celebrating genuine innovators. Until then, we may have to remain content with a handful of Nobel Prizes—or equivalent global honours—arriving only occasionally.

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S N BOSE STATISTICS

One hundred years ago, in July of 1924, a brilliant Indian physicist changed the way that scientists count. **Satyendra Nath Bose** (1894 – 1974) mailed a letter to **Albert Einstein** enclosed with a manuscript containing a new derivation of **Planck's law** of blackbody radiation. Bose had used a radical approach that went beyond the classical statistics of Maxwell and Boltzmann by counting the different ways that photons can fill a volume of space. His key insight was the **indistinguishability of photons** as quantum particles. Today, the indistinguishability of quantum particles is the foundational element of quantum statistics that governs how fundamental particles combine to make up all the matter of the universe. At the time, neither Bose nor Einstein realized just how radical his approach was, until Einstein, using Bose's idea, derived the behaviour of material particles under conditions similar to black-body radiation, predicting a new state of condensed matter [1]. It would take scientists 70 years to finally demonstrate "**Bose-Einstein**" **condensation** in a laboratory in Boulder, Colorado in 1995.

Early Days of the Photon

As outlined in a previous blog (see *Who Invented the Quantum? Einstein versus Planck*), Max Planck was a reluctant revolutionary. He was led, almost against his will, in 1900 to postulate a quantized interaction between electromagnetic radiation and the atoms in the walls of a black-body enclosure. He could not break free from the hold of classical physics, assuming classical properties for the radiation and assigning the quantum only to the "interaction" with matter. It was Einstein, five years later in 1905, who took the bold step of assigning quantum properties to the radiation field itself, inventing the idea of the "**photon**" (named years later by the American chemist Gilbert Lewis) as the first quantum particle.

Despite the vast potential opened by Einstein's theory of the photon, quantum physics languished for nearly 20 years from 1905 to 1924 as semi-classical approaches dominated the thinking of Niels Bohr in Copenhagen, and Max Born in Göttingen, and Arnold Sommerfeld in Munich, as they grappled with wave-particle duality.

The existence of the photon, first doubted by almost everyone, was confirmed in 1915 by Robert Millikan's careful measurement of the photoelectric effect. But even then, skepticism remained until Arthur Compton demonstrated experimentally in 1923 that the scattering of photons by electrons could only be explained if photons carried discrete energy and momentum in precisely the way that Einstein's theory required.

Despite the success of Einstein's photon by 1923, derivations of the Planck law still used a purely wave-based approach to count the number of electromagnetic standing waves that a cavity could support. Bose would change that by deriving the Planck law using purely quantum methods.

The Quantum Derivation by Bose

Satyendra Nath Bose was born in 1894 in Calcutta, the old British capital city of India, now Kolkata. He excelled at his studies, especially in mathematics, and received a lecturer post at the University of Calcutta from 1916 to 1921, when he moved into a professorship position at the new University of Dhaka.

One day, as he was preparing a class lecture on the derivation of Planck's law:

$$\rho(\nu,T)=\frac{8\pi\nu^2 d\nu}{c^3}\left(\frac{h\nu}{e^{h\nu/k_BT}-1}\right)$$

He became dissatisfied with the usual way it was presented in textbooks, based on standing waves in the cavity, and he flipped the problem. Rather than deriving the number of standing wave modes in *real space*, he considered counting the number of ways a photon would fill up *phase space*.

Phase space is the natural dynamical space of Hamiltonian systems [2], such as collections of quantum particles like photons, in which the axes of the space are defined by the positions and momenta of the particles. The differential volume of phase space dV_{PS} occupied by a single photon is given by:

$$dV_{PS} = V 4\pi p^2 dp$$

Using Einstein's formula for the relationship between momentum and frequency:

$$p = h\nu / c$$

where h is Planck's constant, yields:

$$dV_{PS} = V 4\pi \frac{h^3 \nu^2}{c^3} d\nu$$

No quantum particle can have its position and momentum defined arbitrarily precisely because of Heisenberg's uncertainty principle, requiring phase space volumes to be resolvable only to within a minimum reducible volume element given by h3. Therefore, the number of states in phase space occupied by the single photon are obtained by dividing dV_{PS} by h^3 to yield:

$$\frac{dN}{V} = \frac{4\pi \nu^2 d\nu}{c^3}$$

which is half of the prefactor in the Planck law. Several comments are now necessary.

First, when Bose did this derivation, there was no Heisenberg Uncertainty relationship—that would come years later in 1927. Bose was guided, instead, by the work of Bohr and Sommerfeld and Ehrenfest who emphasized the role played by the action principle in quantum systems. Phase space dimensions are counted in units of action, and the quantized unit of action is given by Planck's constant h, hence quantized volumes of action in phase space are given by h3. By taking this step, Bose was anticipating Heisenberg by nearly three years.

Second, Bose knew that his phase space volume was half of the prefactor in Planck's law. But since he was counting states, he reasoned that this meant that each photon had two internal degrees of freedom. A possibility he considered to account for this was that the photon might have a **spin** that could be aligned, or anti-aligned, with the momentum of the photon [3, 4]. How he thought of spin is hard to fathom, because the spin of the electron, proposed by Uhlenbeck and Goudsmit, was still two years away.

But Bose was not finished. The derivation, so far, is just how much phase space volume is accessible to a single photon. The next step is to count the different ways that many photons can fill up phase space. For this he used (bringing in the factor of 2 for spin):

$$A = \frac{8\pi \nu^2 d\nu}{c^3} = \sum_n p_n$$

where p_n is the probability that a volume of phase space contains n photons, plus he used the usual conditions on energy and number:

$$E = Nh\nu$$
$$N = \sum_n n p_n$$

The probability for all the different permutations for how photons can occupy phase space is then given by:

$$W = \frac{A!}{p_0!p_1!\ldots}$$

A third comment is now necessary: By assuming this probability, Bose was discounting situations where the photons could be distinguished from one another. This indistinguishability of quantum particles is absolutely fundamental to our understanding today of quantum statistics, but Bose was using it implicitly for the first time here.

The final distribution of photons at a given temperature T is found by maximizing the entropy of the system:

$$S = k_B \ln W$$

subject to the conditions of photon energy and number. Bose found the occupancy probabilities to be:

$$p_n = B\exp\left(-nh\nu / k_B T\right)$$

with a coefficient B to be found next by using this in the expression for the geometric series:

$$\begin{aligned} A &= \sum_n p_n = B\sum_n \left[\exp\left(-h\nu / k_B T\right)\right]^n \\ &= \frac{B}{1-\exp\left(-h\nu / k_B T\right)} \end{aligned}$$

yielding:

$$B = A\left[1-\exp\left(-h\nu / k_B T\right)\right]$$

Also, from the total number of photons:

$$\begin{aligned} N &= \sum_n np_n \\ &= \sum_n nA\left[1-\exp\left(-h\nu / k_B T\right)\right]\exp\left(-nh\nu / k_B T\right) \\ &= A\frac{\exp\left(-h\nu / k_B T\right)}{1-\exp\left(-h\nu / k_B T\right)} \end{aligned}$$

And, from the total energy:

$$E = Nh\nu = \frac{8\pi h\nu^3 d\nu}{c^3}\frac{\exp\left(-h\nu / k_B T\right)}{1-\exp\left(-h\nu / k_B T\right)}$$

Bose obtained, finally:

$$E = \frac{8\pi\nu^2 d\nu}{c^3}\left[\frac{h\nu}{\exp\left(h\nu / k_B T\right)-1}\right]$$

which is **Planck's law**.

This derivation uses nothing but the counting of quanta in phase space. There are no standing waves. It is a purely quantum calculation—the first of its kind.

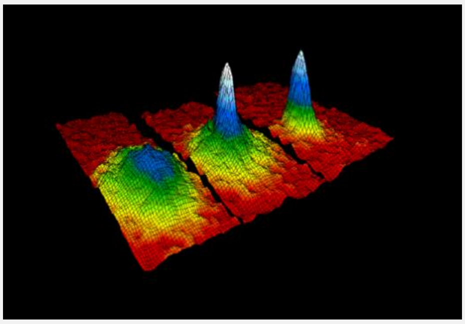
Enter Einstein

As usual with revolutionary approaches, Bose's initial manuscript submitted to the *British Philosophical Magazine* was rejected. But he was convinced that he had attained something significant, so he wrote his letter to Einstein containing his manuscript, asking that if Einstein found merit in the derivation, then perhaps he could have it translated into German and submitted to the *Zeitschrift für Physik*. (That Bose would approach Einstein with this request seems bold, but they had communicated some years before when Bose had translated Einstein's theory of General Relativity into English.)

Indeed, Einstein recognized immediately what Bose had accomplished, and he translated the manuscript himself into German and submitted it to the *Zeitschrift* on July 2, 1924 [5].

During his translation, Einstein did not feel that Bose's conjecture about photon spin was defensible, so he changed the wording to attribute the factor of 2 in the derivation to the two polarizations of light (a semi-classical concept), so Einstein actually backtracked a little from what Bose originally intended as a fully quantum derivation. The existence of photon spin was confirmed by C. V. Raman in 1931 [6].

In late 1924, Einstein applied Bose's concepts to an ideal gas of material atoms and predicted that at low temperatures the gas would condense into a new state of matter known today as a Bose-Einstein condensate [1]. Matter differs from photons because the conservation of atom number introduces a finite chemical potential to the problem of matter condensation that is not present in the Planck law.



Experimental evidence for the Bose-Einstein condensate in an atomic vapor [7].

Paul Dirac, in 1945, enshrined the name of Bose by coining the phrase "Boson" to refer to a particle of integer spin, just as he coined "Fermion" after Enrico Fermi to refer to a particle of half-integer spin. All quantum statistics were encased by these two types of quantum particle until 1982, when Frank Wilczek coined the term "Anyon" to describe the quantum statistics of particles confined to two dimensions whose behaviors vary between those of a boson and of a fermion.

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EINSTEIN'S ANNUS MIRABILIS: THE YEAR THAT CHANGED PHYSICS FOREVER

In 1905, a 26-year-old patent clerk at Bern published four papers that transformed physics. They explained the particle nature of light, the atomic structure of matter, the relativity of space and time, and the equivalence of mass and energy. This "Annus Mirabilis," or miracle year, is remembered not only for the scientific breakthroughs it delivered but also for how it redefined the very character of physics.

Clouds on the Horizon

At the dawn of the twentieth century, physics appeared almost complete. Newton's mechanics and Maxwell's electromagnetism provided a majestic framework that seemed to describe the natural world in full. Yet, as Lord Kelvin famously remarked in 1900, "two small clouds" remained. One was the failure to explain the spectrum of blackbody radiation; the other, the puzzling results of the Michelson–Morley experiment, which refused to reveal the elusive ether that was supposed to carry light waves.

Beneath these clouds lay deeper questions. Was light truly a wave, or could it sometimes behave like particles? Were atoms real, or were they only convenient fictions in the equations of chemistry? And was time itself universal, ticking identically for all, or could it be malleable? Into this uncertain landscape stepped Albert Einstein, a young man working not in a laboratory but at Swiss Patent Office.

The Patent Clerk of Bern

Einstein's 1905 story hardly fits into the image of an established scientist. Having failed to secure an academic post after graduation, he examined patent applications by day and pondered physics by night. Yet, his detachment from academic orthodoxy gave him freedom. Alongside a few friends, they jokingly called themselves the *Olympia Academy*, they debated philosophy, read widely, and cultivated an independent style of thinking.

In March of that year, he began to publish a series of papers in *Annalen der Physik*. What followed was nothing short of a miracle.

1. The Photoelectric Effect (March 1905)

For years, the photoelectric effect had baffled experimentalists. Heinrich Hertz had noticed that ultraviolet light striking a metal surface could release electrons. But the details were troubling. According to the wave theory, the energy of emitted electrons should depend on the intensity of light. In practice, however, the decisive factor was its frequency.

Einstein proposed that light itself was composed of discrete energy quanta. Each carried an energy

$$E = h\nu$$

with h as Planck's constant and ν the frequency. When a photon struck a metal, it could transfer its energy to an electron. If that energy exceeded the metal's work function W, the electron would be released with kinetic energy

$K_{max} = h\nu - W$

This bold idea that light could act like particles, challenged the wave picture that had triumphed since Maxwell. Initially resisted, it would eventually earn Einstein the Nobel Prize. More importantly, it marked the birth of quantum theory.

2. Brownian Motion (May 1905)

A few months later, Einstein turned his attention to another puzzle. Since Robert Brown's observations in 1827, the erratic jiggling of pollen grains in water had remained unexplained. Was it a biological property, or was something deeper at work?

Einstein treated the suspended particles as tiny spheres buffeted randomly by molecules of the liquid unseen, but numerous. From this model he derived a quantitative relation for their mean squared displacement:

$\langle x^2 \rangle = 2k_BTt / 3\pi\eta a$

where a is the particle radius, η the viscosity of the fluid, T the temperature, and t the time.

This formula transformed a curious observation into a decisive proof of the atomic hypothesis. Jean Perrin's meticulous experiments later confirmed Einstein's predictions and silenced the sceptics who still doubted the reality of atoms.

3. Special Relativity (June 1905)

The failure to detect the "ether" in the Michelson–Morley experiment had unsettled physicists. How could the speed of light remain constant regardless of the observer's motion?

Einstein's bold postulates were:

1. The laws of physics are the same in all inertial frames.
2. The speed of light in vacuum is constant for all observers, regardless of their motion.

From these, he derived consequences that overturned centuries of Newtonian intuition:

- **Time dilation:**

$\Delta t' = \gamma \Delta t$ where $\gamma = 1/(1-v^2/c^2)^{1/2}$

- **Length contraction:**

$L' = L/\gamma$

- **Relativity of simultaneity:** Events that are simultaneous in one frame may not be so in another.

These results redefined space and time not as absolute but as relative and interconnected dimensions of a four-dimensional continuum.

4. Mass–Energy Equivalence (September 1905)

As if the three papers were not enough, Einstein added a short but profound note in September. He asked: does the inertia of a body depend on its energy content? The answer was a now-familiar equation:
$E = mc^2$

This compact formula revealed that mass itself is a reservoir of energy. A small amount of matter could, in principle, unleash vast power. From the fusion that powers the stars, to the fission in nuclear reactors, this insight became one of the cornerstones of modern science and technology.

The Legacy of 1905

Each paper is a milestone in the history of the twentieth century physics. Together, they redefined physics. Quantum mechanics, statistical physics, relativity, and nuclear science all trace their lineage to that single year.

Einstein's miracle year also reshaped the image of science itself. Here was no laboratory, no director, no senior professor, but a patent clerk whose imagination leapt beyond convention. His achievements remind us that creativity often thrives outside established paths, and that persistence and curiosity can triumph over circumstance.

A Personal Dimension

It is remarkable that these breakthroughs emerged from someone outside the traditional academic establishment. Working as a patent examiner in Bern, Einstein often joked that his job trained him to think independently evaluating ideas not for pedigree but for internal consistency. He carried notebooks filled with thought experiments: a man chasing a beam of light, or a clock aboard a moving train.

Einstein's modest living, his friendships with a small discussion group he called the *Olympia Academy*, and his refusal to accept dogma all contributed to his independence of thought. His story illustrates that creativity in science is not bound by circumstance but thrives on persistence and curiosity.

Reflections on Annus Mirabilis

In retrospection, *Annus Mirabilis* was not merely about solving puzzles. It was about opening doors. The young man in Bern showed that physics was far from complete, that the world was stranger and more beautiful than Newton's clockwork universe suggested.

Just as Lord Kelvin's "two clouds" signalled storms, Einstein's lightning bolts illuminated new landscapes like quantum, relativistic, and atomic. Today, more than a century later, the echoes of 1905 still shape every laboratory and every classroom.

Physics continues to evolve, but Einstein's miracle year endures as a testament to imagination at work: a reminder that revolutions can begin in the humblest of places, and that even ordinary desks in patent offices can be launch pads to the cosmos.

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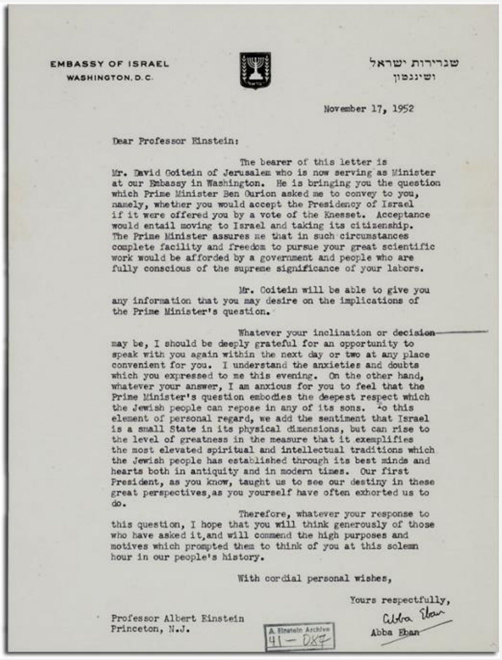
Einstein's Political Invitation – And His Graceful Decline

In 1952 the newly established State of Israel offered Einstein its presidency (a largely ceremonial post at that time). He declined, citing his lack of experience in political leadership and believing someone else would be more suited



EMBASSY OF ISRAEL
WASHINGTON, D.C.

שגרירות ישראל
וושינגטון

November 17, 1952

Dear Professor Einstein:

The bearer of this letter is Mr. David Goitein of Jerusalem who is now serving as Minister at our Embassy in Washington. He is bringing you the question which Prime Minister Ben Gurion asked me to convey to you, namely, whether you would accept the Presidency of Israel if it were offered you by a vote of the Knesset. Acceptance would entail moving to Israel and taking its citizenship. The Prime Minister assures me that in such circumstances complete facility and freedom to pursue your great scientific work would be afforded by a government and people who are fully conscious of the supreme significance of your labors.

Mr. Goitein will be able to give you any information that you may desire on the implications of the Prime Minister's question.

Whatever your inclination or decision may be, I should be deeply grateful for an opportunity to speak with you again within the next day or two at any place convenient for you. I understand the anxieties and doubts which you expressed to me this evening. On the other hand, whatever your answer, I am anxious for you to feel that the Prime Minister's question embodies the deepest respect which the Jewish people can repose in any of its sons. To this element of personal regard, we add the sentiment that Israel is a small State in its physical dimensions, but can rise to the level of greatness in the measure that it exemplifies the most elevated spiritual and intellectual traditions which the Jewish people has established through its best minds and hearts both in antiquity and in modern times. Our first President, as you know, taught us to see our destiny in these great perspectives, as you yourself have often exhorted us to do.

Therefore, whatever your response to this question, I hope that you will think generously of those who have asked it, and will commend the high purposes and motives which prompted them to think of you at this solemn hour in our people's history.

With cordial personal wishes,

Yours respectfully,
Abba Eban
Abba Eban

Professor Albert Einstein
Princeton, N.J.

A. Einstein Archive
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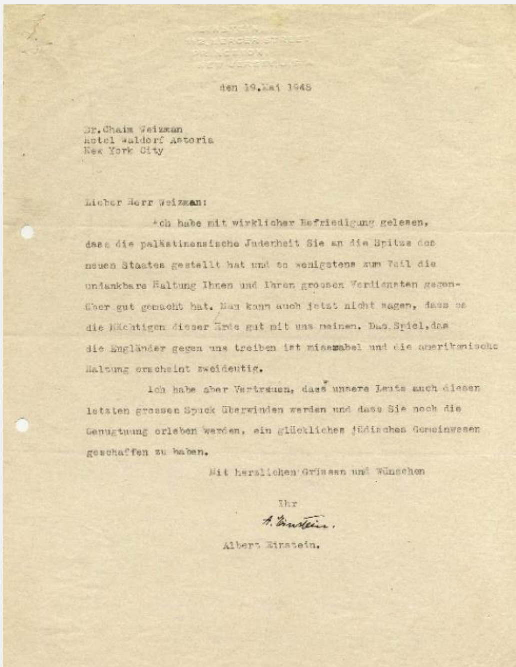
Letter from Abba Eban on behalf of David Ben-Gurion offering the presidency of Israel



den 19. Mai 1948

Dr. Chaim Weizman
Hotel Waldorf Astoria
New York City

Lieber Herr Weizman:

Ich habe mit wirklicher Befriedigung gelesen, dass die palästinensische Judenheit Sie an die Spitze des neuen Staates gestellt hat und so wenigstens zum Teil die undankbare Haltung Ihnen und Ihren grossen Verdiensten gegenüber gut gemacht hat. Man kann auch jetzt nicht sagen, dass es die Mächtigen dieser Erde gut mit uns meinen. Das Spiel, das die Engländer gegen uns treiben ist miserabel und die amerikanische Haltung erscheint zweideutig.

Ich habe aber Vertrauen, dass unsere Leute auch diesen letzten grossen Spuck überwinden werden und dass Sie noch die Genugtuung erleben werden, ein glückliches jüdisches Gemeinwesen geschaffen zu haben.

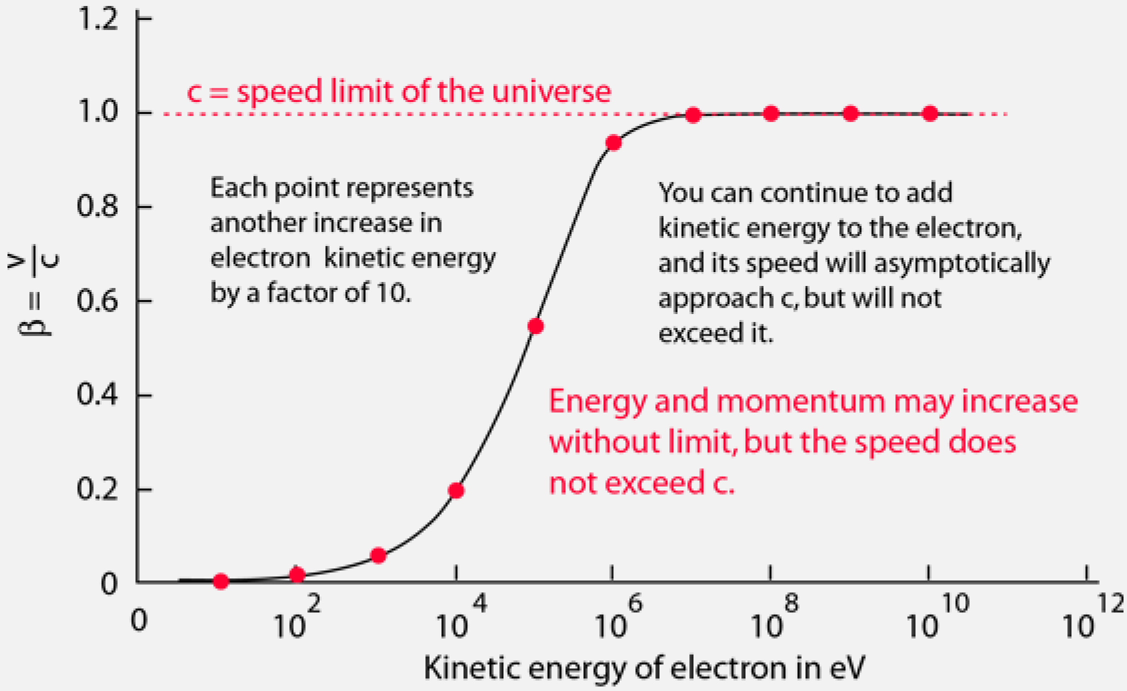
Mit herzlichen Grüssen und Wünschen

Ihr
A. Einstein.
Albert Einstein.

Einstein's personal response

UNIVERSAL LIMIT OF LIGHT SPEED

The *speed of light c* is said to be the speed limit of the universe because nothing can be accelerated to the speed of light with respect to you. A common way of describing this situation is to say that as an object approaches the speed of light, its mass increases and more force must be exerted to produce a given acceleration. There are difficulties with the *"relativistic _increasing mass"* perspective, and it is generally preferrable to say that the *relativistic momentum* and *relativistic energy* approach infinity at the speed of light. The term relativistic is used for micro particles like electron, muon , etc., moving close to the speed of light . Since the *net external applied force* is equal to the rate of change of momentum and the work done is equal to the change in energy, it would take an infinite time and an infinite amount of work to accelerate an object to the speed of light.



A common resistance to the speed limit is to suggest that you just accelerate two different objects to more than half of the speed of light and point them toward each other, giving a relative speed greater than c. But that doesn't work! Time and space are interwoven in such a way that no one observer ever sees another object moving toward them at greater than c. The *Einstein relativistic velocity addition* deals with the transformation of velocities, always yielding a relative velocity less than c. It doesn't agree with your common sense, but it appears to be the way the universe works.

Speed of Light c

Measured value:

Recent experiments give c as

c = 299,792,458 ± 1.2 m/s

but the uncertainties in this value are chiefly those of comparisons to previous standards for the length of the meter. Therefore the above speed of light has been adopted as a standard value and the length of the meter is redefined to be consistent with this value:

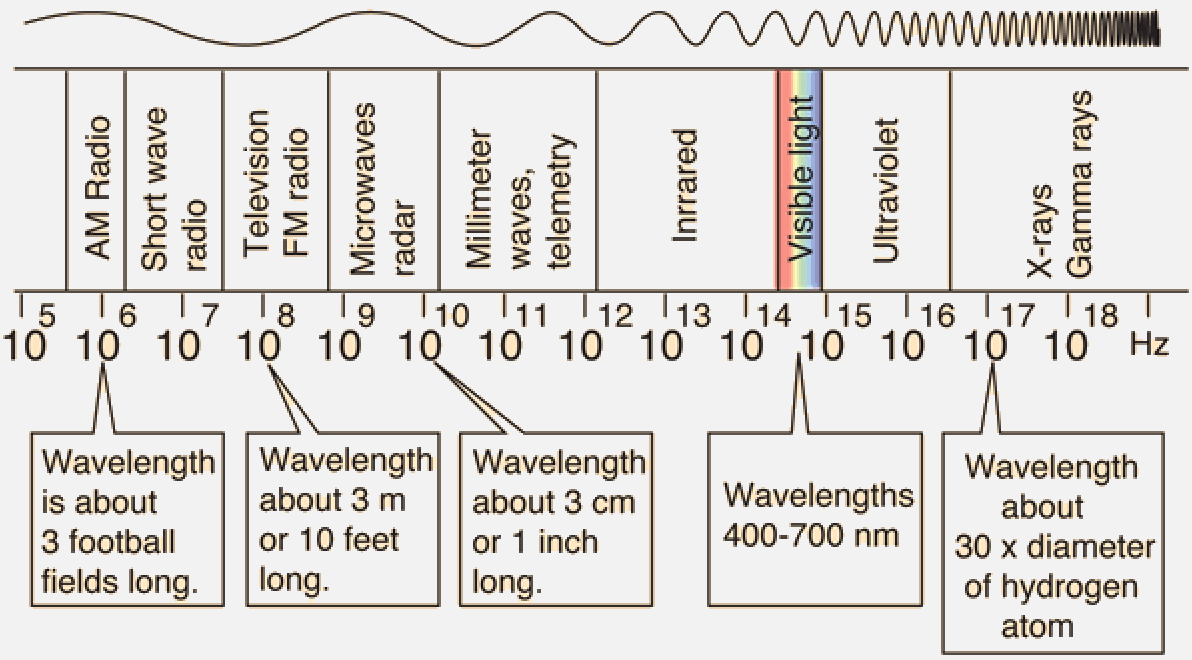
c ≡ 299,792,458 m/s

History of measurement:

Experimental measurements of the speed of light have been refined progressively since the seventeenth century. Until the year 1850 the propagation of light was viewed in mechanical terms and it was presumed that it moved in a medium called the "luminiferous ether" and subsequently as electromagnetic wave .The first measurement of the speed of light is attributed to Danish astronomer Roemer. He measured systematic variations in the times at which the moons of Jupiter moved into the planet's shadow. Attributing these variations to different transit times for the light coming from Jupiter's orbit to the earth, he was able to calculate the speed of light.

Electromagnetic wave nature of light:

In vacuum, all electromagnetic waves travel at c, the speed of light.



$$c = \nu\lambda$$

Also commonly written $v = f\lambda$

velocity = frequency x wavelength

The speed of light which is related to the electric and magnetic properties of the medium/vacuum, can be expressed as

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

ε_0 = electric permittivity

μ_0 = magnetic permeability

Relativistic Increasing Mass"

The relativistic increase in mass m with speed v is given by the expression

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \gamma m_0 \qquad m_0 = \text{"rest mass"}$$

It follows from the *Lorentz transformation*, when collisions are described from a fixed and moving reference frame, where it arises as a result of conservation of momentum and also from the *relativistic energy* expression.The relativistic increase in mass is associated with speed of light c, **the *speed limit of the universe***. This increased relativistic increasing in mass is evident in cyclotrons and other accelerators where the speed approaches c. Exploring the calculation above will show that you have to reach 14% of the speed of light, or about 42 million m/s before you change the effective mass by 1%.

Relativistic Momentum

The relativistic momentum is given by

$$p = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}} = \gamma m_0 v$$

Relativistic Energy

The famous Einstein relationship for energy

$$E = mc^2$$

where the relativistic increasing in mass m is given by the energy divided by c^2. This suggests that this "m" is really about the energy, and that the real mass is the rest mass m_0.

Kinetic energy of a relativistic particle can be calculated from

$$KE = mc^2 - m_0 c^2$$

where $m_o c^2$ is the rest mass energy

The relativistic energy of a particle can also be expressed in terms of its momentum in the expression

$$E = mc^2 = \sqrt{p^2 c^2 + m_0^2 c^4}$$

Limitations on Newton's 2nd Law

One of the best known relationships in physics is *Newton's 2nd Law*

$$F = ma$$

Though it is extremely useful for the prediction of motion under certain constraints, it is not a fundamental principle like the conservation laws.The more fundamental relationship is

$$F_{net\ external} = \frac{d(mv)}{dt} = m\frac{dv}{dt} + v\frac{dm}{dt}$$

The net external force should be defined as the rate of change of *momentum;* This expression turns out to be F= ma , only if the mass is constant. Since the mass increases relativistically as the speed approaches the speed of light, F=ma is seen to be strictly a non-relativistic relationship which applies to the acceleration of constant mass objects.

Classical Velocity Addition:

Example:

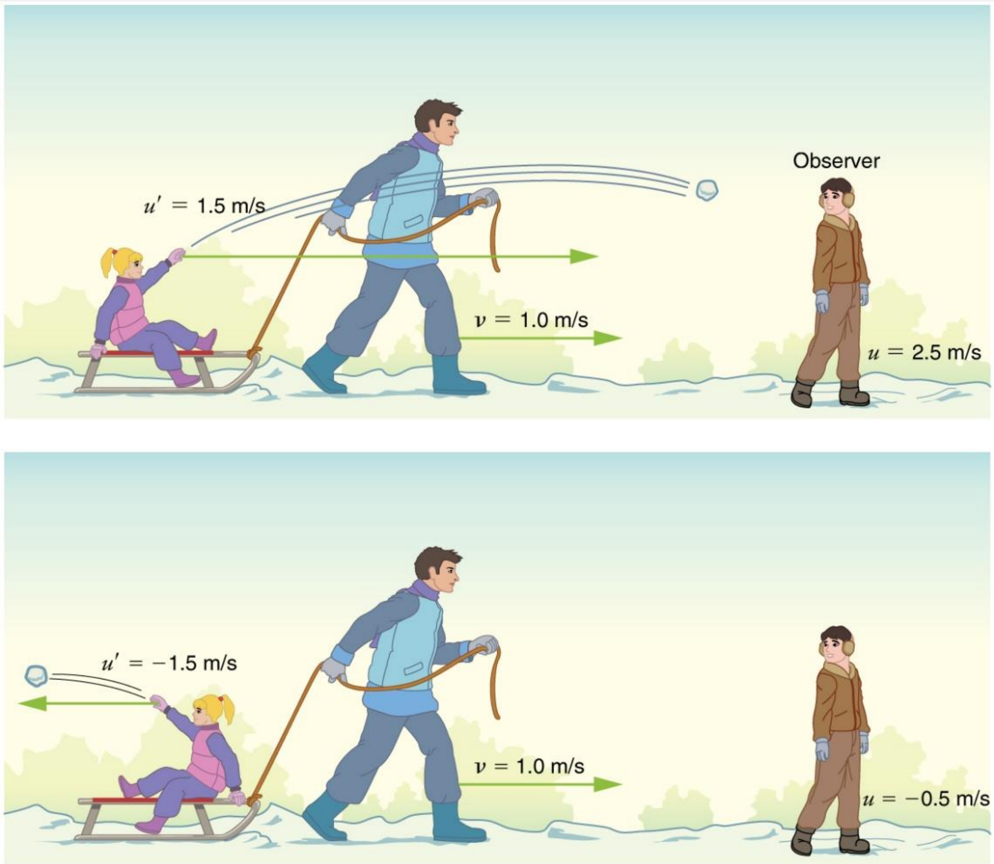
For simplicity, we restrict our consideration of velocity addition to one-dimensional motion. Classically, velocities add like regular numbers in one-dimensional motion(See Figure). Suppose, for example, a girl is riding in a sled at a speed 1.0 m/s relative to an observer. She throws a snowball first forward, then backward at a speed of 1.5 m/s relative to the sled. We denote direction with plus and minus signs in one dimension; in this example, forward is positive.

Let v be the velocity of the sled relative to the Earth, u the velocity of the snowball relative to the Earth-bound observer, and u' velocity of the snowball relative to the sled, then

$$u = v + u'$$

Thus, when the girl throws the snowball forward, $u = 1.0 m/s + 1.5 m/s = 2.5 m/s$. It makes good intuitive sense that the snowball will head towards the Earth-bound observer faster, because it is thrown forward from a moving vehicle.

When the girl throws the snowball backward, $u = 1.0 m/s + (-1.5 m/s) = -0.5 m/s$. The minus sign means the snowball moves away from the Earth-bound observer. In this case, the snowball will move away from the the Earth-bound observer slower.



Einstein relativistic velocity addition:

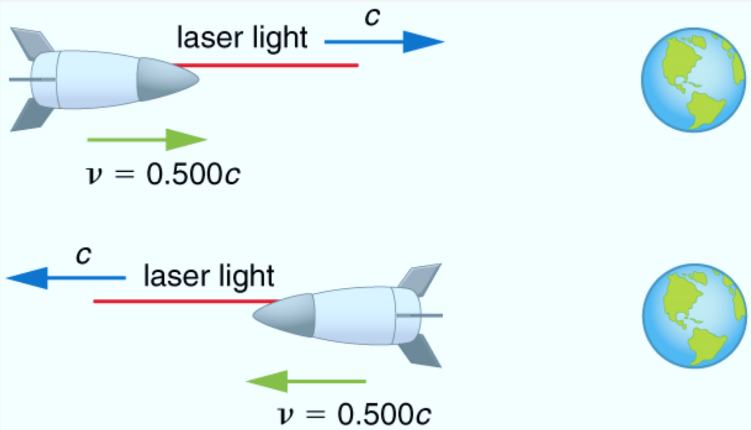
The correct formula for one-dimensional Einstein relativistic velocity addition is

$$u = \frac{v + u'}{1 + \frac{vu'}{c^2}},$$

where v is the relative velocity between two observers, u is the velocity of an object relative to one observer, and u' is the velocity relative to the other observer. (For ease of visualization, we often choose to measure u in our reference frame, while someone moving at v relative to us measures u'.) Note that the term $\frac{vu'}{c^2}$ becomes very small at low velocities, and the above expression gives a result very close to classical velocity addition, u=v+u'. As before, we see that classical velocity addition is an excellent approximation to the correct Einstein relativistic velocity addition, for small velocities.

Example1: Showing that the Speed of Light towards an Observer is Constant (in a Vacuum):

Suppose a spaceship heading directly towards the Earth at half the speed of light sends a signal to us on a laser-produced beam of light. Given that the light leaves the ship at speed c as observed from the ship, calculate the speed at which it approaches the Earth



Strategy: Because the light and the spaceship are moving at relativistic speeds, we cannot use simple classical velocity addition. Instead, we can determine the speed at which the light approaches/recedes the Earth using Einstein relativistic velocity addition.

Solution **:**

Case (1) :

1. Identify the knowns: $v=0.500c$; $u'=c$
2. Identify the unknown: u
3. Choose the appropriate equation:

$$u = \frac{v+u'}{1+\frac{vu'}{c^2}},$$

4. Plug the knowns into the equation.

$$u = \frac{v+u'}{1+\frac{vu'}{c^2}} = \frac{0.500c+c}{1+\frac{(0.500C)(c)}{c^2}} = \frac{(0.500+1)c}{1+\frac{0.500c^2}{c^2}} = \frac{1.500c}{1+0.500} = \frac{1.500c}{1.500} = c$$

Case(2) :

$v=-0.500c$; $u'=-c$ and plugging these knowns into the equation , $u=-c$.

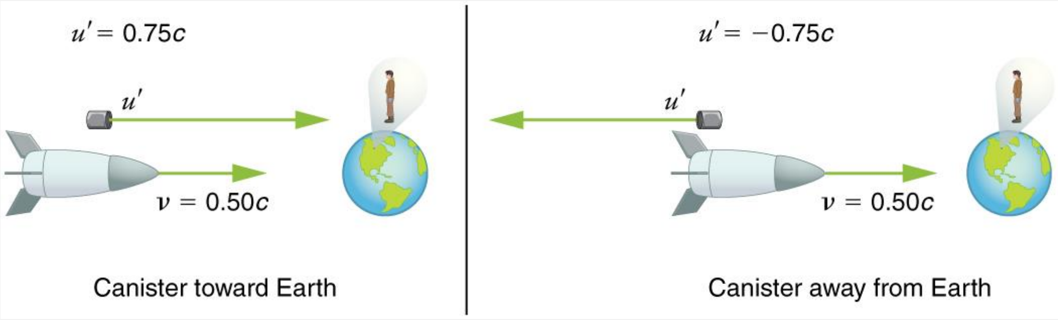
The minus sign indicates light and spaceship are moving away from the Earth-bound observer.

Discussion: Einstein relativistic velocity addition gives the correct result. Light leaves the ship at speed c and same value c is measured by earth bound obsorver. The speed of light is independent of the relative motion of source and observer, whether the observer is on the ship or Earth-bound.

Example2:Comparing the Speed of Light towards and away from an Observer: Relativistic Package Delivery

Suppose the spaceship in the previous example is approaching the Earth at half the speed of light and shoots a canister at a speed of 0.75c.

a. At what velocitywill an Earth-bound observer see the canister if it is shot directly towards the Earth?
b. If it is shot directly away from the Earth?



Strategy: Because the canister and the spaceship are moving at relativistic speeds, we must determine the speed of the canister by an Earth-bound observer using Einstein relativistic velocity addition instead of classical velocity addition.

Solution for (a)

1. Identify the knowns: *v=0.500c* ; *u' =0.750c*
2. Identify the unknown:
3. Choose the appropriate equation:

$$u = \frac{v + u'}{1 + \frac{vu'}{c^2}},$$

4. Plug the knowns into the equation:

$$u = \frac{v + u'}{1 + \frac{vu'}{c^2}} = \frac{0.500c + 0.750c}{1 + \frac{(0.500c)(0.750c)}{c^2}} = \frac{1.250c}{1 + 0.375)} = 0.909c$$

Solution for (b)

1. Identify the knowns: *v=0.500c ; u' = -0.750c*
2. Identify the unknown: *u'*
3. Choose the appropriate equation:

$$u = \frac{v + u'}{1 + \frac{vu'}{c^2}},$$

4. Plug the knowns into the equation:

$$u = \frac{v + u'}{1 + \frac{vu'}{c^2}} = \frac{0.500c + (-0.750c)}{1 + \frac{(0.500C)(-0.750c)}{c^2}} = \frac{-0.250c}{1 - 0.375} = -0.400c$$

Discussion:The minus sign indicates velocity away from the Earth (in the opposite direction from *v*), which means the canister is heading towards the Earth in part (a) and away in part (b), as expected. But relativistic velocities do not add as simply as they do classically. In part (a), the canister does approach the Earth faster, but not at the simple sum of *1.250c*. The total velocity is less than you would get classically. And in part (b), the canister moves away from the Earth at a velocity of *0.400c*, which is faster than the *0.250c* you would expect classically. The velocities are not even symmetric. In part (a) the canister moves *0.409c* faster than the ship relative to the Earth, whereas in part (b) it moves *0.900c* slower than the ship.

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THE DISCOVERY OF NEUTRON STARS

It took over thirty-eight long years from the first hint of the existence of **neutron stars** (1930) to the positive confirmation of their existence (1968). The following is a brief account of the major steps—both theoretical and experimental—during the long journey towards the discovery of neutron stars.

Chandrasekhar Mass Limit for White Dwarfs

White dwarfs are compact stars that are supported by the quantum mechanical pressure of electrons, known as electron degeneracy pressure. As the star's mass increases, so does the density and the energy of the electrons. At a specific mass, the electrons become so compressed that their relativistic degeneracy pressure can no longer resist the overwhelming force of gravity. This critical mass is now known as the Chandrasekhar mass limit. The Chandrasekhar limit for a stable white dwarf star is approximately 1.4 times the mass of the Sun. What happens to a white dwarf with a mass higher than this mass limit was a question that was raised by Chandrasekhar himself in 1930, without any answer, at that time. Such speculations about the ultimate fates of massive stars drove people to look for the existence of extremely compact objects like neutron stars and black holes.

Discovery of Neutrons

Following the prediction of Rutherford in 1920 about the existence of neutrons in atomic nuclei, James Chadwick discovered the neutron in 1932 with the help of careful experiments bombarding beryllium with alpha particles and observing a neutral radiation that ejected protons from paraffin wax. He calculated the mass of these ejected protons to be roughly equal to the mass of a proton, concluding that the radiation consisted of uncharged particles with a proton-like mass, which he named neutrons.

Thus, he made a very significant contribution to our understanding of the constitution of nuclei. Once neutrons were confirmed to be fermions with spin half, scientists like Lev Landau quickly imagined the possible existence of stable compact stars with neutrons as the main constituent instead of the electrons.

Prediction of Neutron Stars

In 1934, just two years after the discovery of neutrons, Walter Baade and Fritz Zwicky proposed the existence of neutron stars, predicting their formation from the core-collapse of massive stars during supernova explosions. They hypothesized that intense pressure in the collapsing core would force protons and electrons to combine, creating a dense object composed almost entirely of neutrons. Their theory was revolutionary at the time and hence not taken seriously. Their work laid the groundwork for future understanding of the universe's evolution and the life cycles of massive stars.

Rotating Neutron Stars

Young Italian physicist Franco Pacini predicted that a rapidly rotating neutron star with an off-axis powerful magnetic dipole would emit strong electromagnetic radiation that would be losing its rotational energy over time. He proposed this idea in 1967, shortly before the accidental discovery of pulsars. Pacini further suggested that the rotational energy could be transferred to the surrounding supernova remnant, like the Crab Nebula. Subsequent discovery of a pulsar in the center of the Crab Nebula validated his ideas. He also suggested that as the neutron star radiates energy, its rotation slows down, a process known as "spin-down"—a prediction that was confirmed later.

Discovery of Pulsars

In the mid-1960s at the Mullard Radio Astronomy Observatory near Cambridge, Antony Hewish led a team to build a large radio telescope array covering 4.5 acres. The primary goal of the telescope was to study quasars using a technique called interplanetary scintillation (IPS). The IPS technique relies on fluctuations in radio waves as they pass through the solar wind to measure the angular size of radio sources. The telescope was completed in 1967 and it generated over 30 meters of paper data every day from its chart recorders.

His graduate student Jocelyn Bell's task was to manually analyze this data, looking for the tell-tale "twinkling" signals of quasars. In August 1967, Bell noticed an unusual signal on the chart records. It was a recurring "bit of scruff" that did not fit the expected pattern of quasars or human-made interference. After months of careful observation, Bell captured a high-speed recording of the signal on November 28, 1967. This confirmed that the signal was a series of perfectly regular pulses, occurring every 1.3 seconds. Due to the extreme regularity of the pulses, Bell and Hewish jokingly referred to the source as "LGM-1," for "Little Green Men," to signify that the signal could have an extra-terrestrial origin.

The LGM hypothesis was disproven when Bell found three more similar signals coming from different parts of the sky. It was highly improbable that multiple alien civilizations would signal Earth in the same manner.

Over the next two months, the team worked to eliminate all other mundane explanations, such as earthly interference. They determined that the signal was a new astronomical phenomenon, which they dubbed "pulsating radio sources," or "pulsars".

The pulses are beams of electromagnetic radiation emitted from the pulsar's magnetic poles. The radiation is observed as a pulse each time the beam sweeps past Earth, much like the light from a rotating lighthouse beacon. The discovery of pulsars was the first observational evidence for neutron stars, objects that were previously only theoretical conjectures. Their existence opened new fields of high-energy astrophysics.

Thomas Gold's Explanation of Pulsars

In 1968, Pacini's hypothesis was used by Thomas Gold to explicitly argue that a rotating, magnetized neutron star was the mechanism behind the observed pulses. A key piece of evidence was the observed spin-down of the Crab pulsar, which demonstrated that the celestial object was slowing down, rather than vibrating. Gold's explanation connected Bell's observational evidence to the theoretical existence of neutron stars, which had been proposed decades earlier by astronomers Walter Baade and Fritz Zwicky.

At the time, other explanations were proposed, such as a pulsating white dwarf or even signals from extra-terrestrial intelligence. Gold's rotating neutron star theory was initially met with scepticism. The model was confirmed by additional observations that demonstrated its predictions: In 1968, a very fast-spinning pulsar with a 33-millisecond period was discovered in the Crab Nebula, a remnant of a supernova observed in 1054.

The pulsar in the Crab Nebula was observed to be slowing down, a natural consequence of a rotating object losing energy over time. The energy lost from the spin-down was enough to power the surrounding nebula, a key confirmation of Gold's model.

Gold had predicted that if his theory was correct, even faster-spinning pulsars with much shorter periods would be found. The discovery of the Crab Pulsar directly supported this prediction.

Gold's interpretation turned the mysterious pulses from Jocelyn Bell's experiments into definitive proof for the existence of neutron stars and established the foundation of our understanding of pulsars today.

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2. Camenzind, Max (2007). *Compact Objects in Astrophysics: White Dwarfs, Neutron Stars and Black Holes*. Springer Science & Business Media.

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PHYSICISTS SOLVE 90-YEAR-OLD PUZZLE OF QUANTUM DAMPED HARMONIC OSCILLATORS

A plucked guitar string can vibrate for seconds before falling silent. A playground swing, emptied of its passenger, will gradually come to rest. These are what physicists call "damped harmonic oscillators" and are well understood in terms of Newton's laws of motion.

But in the tiny world of atoms, things are strange—and operate under the bizarre laws of quantum physics. University of Vermont professor Dennis Clougherty and his student Nam Dinh wondered if there are systems in the atomic world that behave like the vibrating motion of a guitar string in the Newtonian world.

"If so, can we construct a quantum theory of the damped harmonic oscillator?" Clougherty wondered.

In a study published July 7, 2025, in the journal *Physical Review Research*, he and Dinh did just that: found an exact solution to a model that behaves as a "damped quantum harmonic oscillator," they write—a guitar-string type of motion at the scale of atoms.

It turns out that for roughly 90 years, theorists have tried to describe these damped harmonic systems using quantum physics—but with limited success. "The difficulty involves preserving Heisenberg's uncertainty principle, a foundational tenet of quantum physics," says Clougherty, a professor of physics at UVM since 1992.

Unlike the human-scale world of, say, bouncing balls or arcing rockets, the famed Heisenberg uncertainty principle shows that there is a fundamental limit to the precision with which the position and momentum of a particle can be known simultaneously. At the scale of an atom, the more accurately one property is measured, the less accurately the other can be known.

The model studied by the UVM physicists was originally constructed by British physicist Horace Lamb in 1900, before Werner Heisenberg was born, and well before the development of quantum physics. Lamb was interested in describing how a vibrating particle in a solid could lose energy to the solid. Using Newton's laws of motion, Lamb showed that elastic waves created by the particle's motion feed back on the particle itself and cause it to damp—that is, to vibrate with less and less energy over time.

"In classical physics, it is known that when objects vibrate or oscillate, they lose energy due to friction, air resistance, and so on," says Dinh. "But this is not so obvious in the quantum regime."

Clougherty and Dinh (who graduated from UVM in 2024 with a BS in physics, in 2025 with a master's degree, and is now pursuing a Ph.D. in mathematics at UVM) reformulated Lamb's model for the quantum world and found its solution.

"To preserve the uncertainty principle, it is necessary to include in detail the interaction of the atom with all the other atoms in the solid," Clougherty explains. "It's a so-called many-body problem."

How did they solve this problem? Hold onto your seat. "Through a multimode Bogoliubov transformation, which diagonalizes the Hamiltonian of the system and allows for the determination of its properties," they write, yielding a state called a "multimode squeezed vacuum." If you missed a bit of that, suffice it to say that the UVM researchers were able to mathematically reformulate Lamb's system so that an atom's oscillating behavior could be fully described in precise terms.

And precisely locating the position of one atom could lead to something like the world's tiniest tape measure: new methods for measuring quantum distances and other ultra-precision sensor technologies. These potential applications emerge from an important consequence of the UVM scientists' new work: it predicts how the uncertainty in the position of the atom changes with the interaction to the other atoms in the solid. "By reducing this uncertainty, one can measure position to an accuracy below the standard quantum limit," Clougherty says.

In physics, there are some ultimate limits, like the speed of light and that Heisenberg's uncertainty principle prevents perfect measurement of a particle. But this uncertainty can be reduced beyond normal limits by certain quantum tricks—in this case, calculating the particle's behaviour in a special "squeezed vacuum" state which reduces the noise of quantum randomness in one variable (location) by increasing it in another (momentum).

This kind of mathematical manoeuvre was behind the creation of the first successful gravitational wave detectors, which can measure changes in distance one thousand times smaller than the nucleus of an atom—and for which the Nobel Prize was awarded in 2017. Who knows what the Vermont theorists' discovery of a new quantum solution to Lamb's century-old model might reveal.

Reference

Dennis P. Clougherty et al, "Quantum Lamb model," *Physical Review Research* (2025).

Author: Joshua Brown, University of Vermont & edited by Robert Egan

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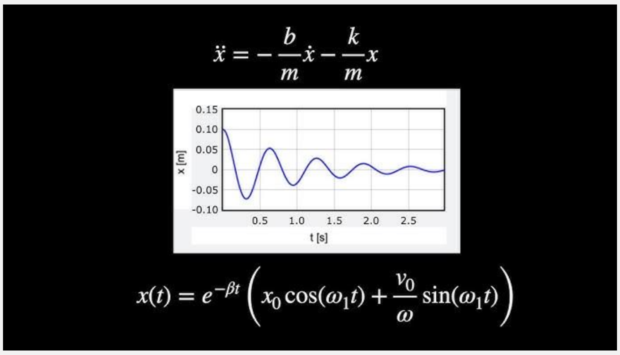
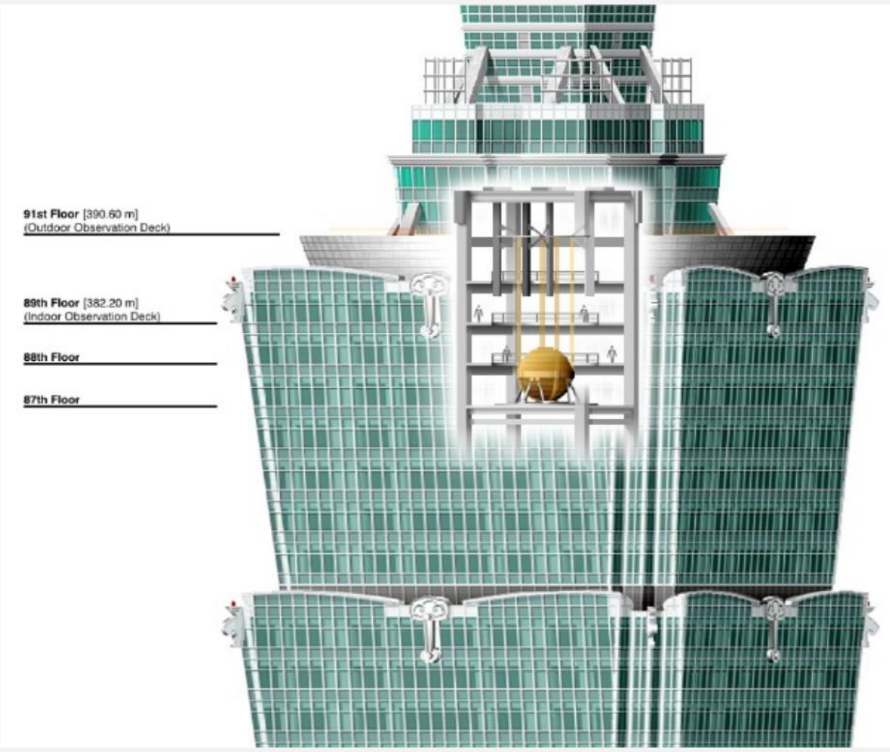
Damped harmonic oscillator





That big ball you might see near the top of a skyscraper? It's a tuned mass damper really acting like a damped oscillator, chewing up oscillation energy so the building stays steady

PHILIPP LENARD – A BIOGRAPHICAL SKETCH

Son of a wine merchant in a city called Bratislava in Hungary, Philipp Edward Anton Lenard was educated in Budapest and in Germany. He worked under Heinrich Hertz and then became his assistant in the University of Bonn. Later he was invited to occupy a chair in Physics at the University of Heidelberg where he led a group which was said to be, 'one of the most active in entire Germany'. The group was investigating on phosphorescence and photoelectric action.

Being a brilliant experimentalist, Lenard most importantly proved that cathode rays are actually a beam of electrons. He invented a device known by his name as the 'Lenard window '. He had fitted a thin metal foil replacing a part of glass in an evacuated tube and showed that the cathode ray beam passes through the foil (surprisingly, it acted just like an invisible window to the beam yet keeping the vacuum cover of the tube unharmed). Further, he showed that, the beam so emerged from the tube's wall, could even be directed on a target placed outside the tube. In this process, it was sure that, there is a transmission of electrons happening via the body of the metal foil. Transmission of electrons through the foil was perceived with wonder and awe by the physics community. The intensity of transmission was so high, it was a straight demonstration that, the electrons can actually pass through the atoms in the foil. That observation in turn ended up proving a very crucial point that, most of the space in the body of the atom must be empty since otherwise, electrons being material particles can never pass through the body of the metal foil if its atoms possess bodies stuffed with matter of some type. Thus the J J Thomson's plum pudding model of the atom completely filled with positive jelly, faced a direct challenge for the first time. (It is yet another story regarding, Rutherford proving experimentally a few years later that, not only the body of an atom is completely empty but, it has all its positive charge concentrated in a tiny space at the atom's body center.) For this work, Lenard was awarded the Nobel prize in Physics for the year 1905(?!) during which year Germany had the distinction of winning also the Nobel prizes for chemistry (J.F. Baeyer) and for medicine (Robert Koch). In around 1903, continuing his Guru Hertz's work, Lenard also had made some crucial observations regarding the Photo electric effect but stopped there falling short of explaining why it was happening so. Then in 1905, Einstein theoretically accounted for all the Lenard's observations in Photoelectric effect by bringing in the concept of what was called 'Light Corpuscles' for the first time. (The same light corpuscles were later renamed as 'Photons' by Gilbert Lewis a chemist, in 1923.) Lenard became Professor in the Heidelberg University in the year 1907.

Initially Lenard had regards for Einstein and even thought of inviting him to a chair in his university in the year 1913. But during the time of World War, his attitude changed.

In 1918 the war came to an end. King Wilhelm abdicated to Holland. A new government, not anymore a monarchy but one of republican style, which came to be known as 'Weimar republic' was established in Germany then a war ravaged country. With little or no cash in the Government's treasury, the inflation skyrocketed. Germans lost fortunes overnight. It included the Nobel laureates Laue, as well as Lenard too. Earlier Lenard had exchanged gold for bonds. But the great inflation rendered the bonds worthless. Lenard felt strongly that it was the Jewish politicians who caused the disaster. In 1922 Lenard lost his only son due to malnutrition he suffered during the war. Added to these bouts of sorrow, he brought one more upon himself; he was reprimanded by the University when he didn't fly the flag of his institute at half-mast when the rest of the university observed mourning over the death of a leading politician who happened to be a Jew. Whipped up by mounting anti-Jewish feelings, Lenard walked promptly into the ranks of Hitler's party namely the National Socialists, or Nazis.

Lenard started addressing theoretical Physics in essence as Jewish Physics, in a tone of condemnation and he looked and admired at experimental Physics as Aryan. It is interesting to note what Lenard was to say about his GURU, Heinrich Hertz whom he always held in high esteem. Hertz was half Jewish in the sense his mother was Aryan and father a Jew.

Lenard attributed the remarkable experimental success as due to the Aryan part that Hertz had in his blood, but picked up the shortcomings in Hertz's theoretical work and said it was all due to his Jewish inheritance.

The phenomenal success of relativity theory that brought international fame in few months to the much younger Einstein, pushed Lenard to the limits perhaps fuelled by a raging envy. He became prominent among those who criticised relativity theory of Einstein. Around 1920 Einstein hit back (unnecessarily) with strong terms and refuted the objections. Lenard was infuriated. He along with Stark took commanding positions in the scientific circles in the anti-semitic drive of Nazi regime. While Stark's attack was more politically based, Lenard's was largely on ideological basis. They became the great adversary-duo, inveterate enemy-pair that always challenged Einstein, or anything meritorious that could be associated with Einstein. However, their branding of theoretical physics as Jewish physics was ridiculed by other Physicists as "Whatever they don't understand they call it Jewish". Consequently for Lenard, though considered a first rate experimental Physicst, his competency in theoretical Physics fell under the shadow of doubt.

In the year 1936-37, Lenard authored what he called "German Physics ". In the foreword for the book he offered the clarification for his title mostly denouncing the theoretical work while glorifying the tasks undertaken in experimental investigations. He worked with Stark to formulate some physics to substitute for quantum and relativity theories, but ended up having essentially the classical physics of nineteenth century. There were attempts to include the new experimental data which in reality were left unexplained by their so called German Physics. This was done after Einstein had left Germany once for all. Lenard lived through the Nazi regime, assumed highly influential positions and eventually saw the fall of the Third Reich. He passed away in the year 1947.

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My work has depended on that of others, and … work by other investigators is related to mine. Thus … I have by no means always been numbered among those who pluck the fruit; I have been repeatedly only one of those who planted or cared for the trees.

— Philipp Lenard

IS ASTROLOGY A SCIENCE?

Astrology – the practice of observing the movements of celestial bodies and believing their positions can have an influence on human lives – has been around for about 5,000 years. From the Babylonians in ancient Mesopotamia who inscribed the stars in cuneiform texts and tried to interpret their sway, to today's popular horoscopes, astrology remains an important part of how many interact with the world and make decisions about their futures.[1] But why does it continue to hold such meaning for so many? And does it offer any explanatory power at all?

Is astrology backed by science?

The answer, in short, is no. There is no scientific backing to the conclusions drawn by astrology. But there are many ways that astrology is connected with the human world, as it’s intertwined with the pursuit of knowledge about our place in the cosmos.

The Sun shapes the structure of the day and the seasons, the Moon influences the ocean’s tides, eclipses turn the sky dark, and solar storms create displays of green and purple lights on the Earth’s celestial canvas. Given these observable effects, it makes sense that people throughout history have wondered if the planets' positions could also influence human life on Earth –. whether the alignment of planets and stars affects who we are as people or what happens to us over the course of our lives. But, as Paul Byrne, an associate professor of Earth, Environmental, and Planetary Sciences at Washington University, explains, “there's just no way the motion of planets through the cosmos can affect us”. There would be too many effects to take into account on principal if they were.[2]

“The only way I can think of another planet having any kind of impact on us," he adds, "is if one were to stroll around at night looking up at Mars, say, or Jupiter or Venus – and by not looking where they're going, walk into a lamppost.”

Scientists have also long been using the scientific method to try to corroborate conclusions drawn by astrology to no avail. In the 1980s, American physicist Shawn Carlson conducted a study to test the validity of astrology. He tasked 30 astrologers with looking at astrological birth charts – which map the Sun, Moon, and planets at the time of a person's birth – of 116 people and seeing if they could match each person's birth chart to their correct personality profile. The astrologers, who had never met the participants, were given three personality profiles to choose from for each birth chart. The test was "double-blind", meaning that neither the testers nor the astrologers knew the answers to any of the questions. His results, published in the peer-reviewed journal *Nature*, showed that the astrologers only got a third of the pairings right, which is not statistically better than if they had chosen completely randomly [3]

A test similar to Carlson was recreated more recently in August 2024, where 152 astrologers were asked to match twelve people’s birth charts to questionnaires they’d answered about their personality and life.[4] Once again, the astrologers got less than a third of the matches right and even agreed on their matches among themselves less than a third of the time too. No more than chance.

Another scientific study sought to match the personality and intelligence test results of 15,000 people with their date of birth and found no correlation.[5]

There is some astrology in science, though...

While there is no science in astrology, there is “a tremendous amount of astrology in science,” says physicist Alexander Boxer, author of the book *A Scheme of Heaven: Astrology and the Birth of Science*.[6]

Astrology thrived during early pursuits in science, and it was studied alongside astronomy, mathematics, and medicine. For thousands of years, astrologers were among the earliest practitioners to collect data and attempt to make predictions. Boxer refers to astrology as “the first data analysis enterprise.” In the Roman Empire, astrologers were essentially the “number crunchers" of their time. They spent their time with pen and parchment searching for patterns in the information they collected – a methodology still seen in science today.

Many astronomers during the Renaissance era practiced both astronomy and astrology, which helped maintain detailed observations of the sky. The astronomer Johannes Kepler, known for his laws of planetary motion, also cast horoscopes for the nobility as a means of financial support.

There’s also an epistemological lesson to be learned from the discipline of celestial predictions: astrology is, says Boxer, a pure encapsulation of the ways we naturally react to data as pattern-matching creatures who are seduced by numbers. “All the issues that astrology had to deal with never went away,” says Boxer. “They're part of our human story, of how we see patterns in numbers, sometimes when they're there, and in many cases, when they're not.”

Why is astrology so important for people, then?

Despite its lack of scientific evidence, astrology has endured throughout the years. It’s special to people, and still today many use it for guidance in their life, or even just for entertainment.

According to Paul Clements, a lecturer in arts and cultural policy at Goldsmiths University of London, astrology's lasting popularity is likely because it offers people tools to interpret their lives with and a way to construct one’s sense of identity.[7,8] Astrology is not scientific, says Clements, rather it is symbolic, creative, divinatory, and spiritual and more related to religion than science. The more anxious and insecure people feel the more they look to something that will help them to navigate the problems that life throws up. It gives people a support system to help them understand their unfolding lives. “It offers new ways of thinking about life and who we are,” says Clements. “A way to assuage existential anxiety.”

Interestingly, research has shown that astrology can influence how people feel about themselves. In a 2006 study, scientists had several people read either positive or negative horoscope predictions about themselves and then gave them some tests and tasks to complete.[9] People who read positive horoscope predictions about themselves interpreted ambiguous photographs more optimistically and performed better on both cognitive and creative tasks. Conversely, people who were given negative astrology readings performed worse. This fits with what we know about the expectation effect in psychology: a student is more likely to perform poorly on a cognitive test if there’s a strong expectation that they will (not succeed?).

The core premise of astrology is the belief that people are all intimately connected to the wider cosmos. “This view is fundamental to most worldviews, philosophies and religions, and only rejected by modern Western philosophy and science,” says Nicholas Campion, an astrology historian from the University of Wales Trinity Saint David. “The attraction of astrology is therefore found in the way age-old worldviews provide a sense of belonging and purpose.”[10]

So while there’s no scientific, empirical evidence that astrology works in explaining whether the alignment of planets and stars has any power over our personality, or what happens in our daily life – its emotional pull and its role in helping people make sense of their existence certainly has its power.

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ANECDOTES OF SCIENTISTS

An anecdote is short, amusing or interesting story about real incident or a person. It is generally used to illustrate a point or to make a writing or conversation interesting or engaging, in other words, to add colour. It could be even a personal story used to capture attention or add life to the writing. In everyday conversations, anecdotes are entertaining as well. Anecdotal digression is a common feature in discourses and literary works. Anecdotes become very handy while teaching especially while teaching complicated topics. With the narration of anecdotes, complicated topics can be made easier to grasp and understandable. Many times, students remember anecdotes through their life rather than actual lesson itself. Hence, anecdotes make teaching interesting, absorbing and engaging and enable teachers to connect with students.

Albert Einstein's Slow Start

Albert Einstein was a "Slow Starter". Though he was not a slow learner, but his delayed speech and struggle with rote learning in a rigid traditional system made some people label him as a slow learner. He totally disliked memorizing facts and found traditional methods stifling. Einstein's curious mind made him to question everything and rebel against regimented learning. He failed in the entrance examination to Swiss Federal Polytechnic in his first attempt. In spite of being a slow learner, Einstein was deeply fascinated by mathematics and physics and exhibited natural aptitude for these subjects though his father wanted him to study electrical engineering. He began teaching himself algebra, calculus and Euclidean geometry when he was a twelve years boy. He mastered integral and differential calculus while he was just fourteen. Such was the genius of Einstein.

Three nationalities

Albert Einstein had three nationalities. He was born a German. When left Germany in 1894, he also renounced his German nationality. Otherwise, on attaining the age of sixteen he had to return to Germany. Because, there was a rule that any German after completing sixteen years of age had to compulsorily serve in military But, Einstein had no inclination to join military. Consequently, from 1896 to 1901, Einstein had no citizenship of any country, a stateless person. In 1901, he became a Swiss national on payment of 600 Swiss francs.

In February 1933, while on a visit to the United States, Einstein realised that he could not return to Germany with the rise to power of the Nazis under Germany's new chancellor, Adolf Hitler**.** Einstein became an American Citizen in 1940.

Miracle Year 1905

The year 1905 has been hailed as Einstein's Miracle Year. Einstein published four revolutionary papers which were very original and made fundamental contributions to physics. These papers known as "Annus Mirabilis" are on Photoelectric Effect, Brownian Motion, Special Theory of Relativity and Mass-Energy Equivalence. These papers laid foundation for modern physics. Einstein's miracle year of 1905 is akin to miracle year 1666 when Issac Newton experienced his greatest epiphany.

Olympia Academy

Einstein was very keen to get into the world of academics and to become a scientist. He was not happy with the work in the patent office, Berne, Switzerland though it provided him a living. The office library possessed lot of technical books and journals and few dedicated to science. There were hardly any discussion on scientific matters. In 1902, Einstein and some of his friends formed a group called "Olympia Academy", held regular meetings to discuss science and philosophy. They used to discuss on works of Henri Poincare (French mathematician), Ernst Mach (Austrian Physicist) and David Hume (Scottish Philosopher and Historian) which significantly influenced Einstein's ideas.

Einstein’s Patents

Everyone knows Einstein as a great theoretical physicist, but very few know that Einstein had 50 plus patents for his inventions. Among all the inventions, the most important invention was that of a design of refrigeration system with Leo Szilard. He had about sixteen patents with Leo Szilard. He had patent with Gustav Bucky for light intensity self-adjusting camera, with Rudolf Gold Schimidt for electromagnetic sound reproduction apparatus and design of a blouse.

Einstein was an admirer of Mahatma Gandhi. Albert Einstein called Mahatma Gandhi, "the most enlightened of all the politicians" and, noting that his moral influence would be lasting, stated, "Generations to come, it may well be, will scarce believe that such a one as this ever in flesh and blood walked upon this earth." Einstein appreciated Gandhi's ability to achieve change through non-violence and satyagraha.

Hilarious Dirac: Famous 20th century Physicist

Paul Dirac, regarded as one of the great theoretical physicists of the twentieth century, is famous for discovering the relativistic equation of the electron which now bears his name. The remarkable notion of an antiparticle to each fermion (e.g., the positron as the antiparticle to the electron) arises from his equation. Dirac also coined the terms fermion and boson.

Dirac Unit

Dirac was well known for his extreme brevity in speech. His colleagues and friends at Cambridge playfully defined a "Dirac" as one word per hour.

Dirac, a Silent Observer

In 1929, Paul Dirac and Werner Heisenberg, both still in their twenties and unmarried, were traveling together on a ship to Japan to attend an annual science conference.

Heisenberg used to dance with young girls before dinners, whereas Dirac would sit and observe from a distance. One evening, Dirac asked Heisenberg:"Why do you dance?"
He replied "Well, when there are nice girls, dancing with them is a pleasure.
For this Dirac asked "How do you know beforehand that girls are nice?"
Heisenberg burst out laughing and said, "Are you serious?"

Not Happy with Oppenheimer as a Poet

While living in Göttingen, Dirac and Robert Oppenheimer became good friends. One day, Dirac discovered that Oppenheimer also wrote poetry and criticized this interest: "The aim of science is to make difficult things understandable in an easier way; the aim of poetry is to state simple things in an incomprehensible way. The two are incompatible. I do not understand how a man can work in the frontiers of physics and write poetry at the same time."

Sir Isaac Newton: Father of Classical Mechanics

Sir Isaac Newton was an English polymath: a mathematician, physicist, astronomer, alchemist, author, and inventor. His book *Principia Mathematica*, published in 1687, established classical mechanics on a firm foundation. Newton is aptly called Father of Classical Mechanics. Newton also made seminal contributions to optics and developed calculus years before Gottfried Wilhelm Leibniz. In the *Principia*, Newton formulated the laws of motion and universal gravitation that formed the dominant scientific viewpoint for centuries until it was superseded by Einstein’s theory of relativity.

Premature Birth

Newton was born on **December 25, 1642**, a few months after the death of his father (also named Isaac Newton). His mother gave birth to the child in the seventh month. The baby was so weak that everyone thought he would not survive even the first day, being so tiny he could reportedly be slipped into a big tumbler. Despite this, Newton lived for over eighty years.

Absent-minded Professor

It is said that as a student and later as a professor at Cambridge, Newton had a reputation for being detached, solitary, and even a bit nasty. He had very few close friends and rarely spoke. He used to get obsessed with his work so much that he sometimes forgot to eat. On one occasion, when no one turned up for his class, he is said to have lectured to an empty room.

Shunned spotlight

Newton, who was shy by nature, was hesitant to publish many of his results. His most significant work, on motion and gravity, collected dust in his study room for more than two decades, until his friend and astronomer Edmond Halley urged him to publish and also supported him financially. The resulting magnum opus titled "Principia Mathematica" was finally printed in 1687.

The plague that set the stage for one of Newton's famous inventions

In 1665, due to an outbreak of the bubonic plague in England, Cambridge University was closed for about eighteen months, forcing Newton to return to his home at Woolsthorpe Manor. While sitting in his ancestral apple farm there one day, he saw an apple falling from a tree, providing him with the inspiration to critically analyse and to eventually formulate his celebrated law of universal gravitation.

Invention of the Cat Door

As we are aware, Newton is most famous for formulating laws of motion and universal law of gravitation, but it's also believed that Isaac Newton invented the cat door. When Newton was working on his experiments at the University of Cambridge, he was constantly interrupted by his cat and kittens scratching on the door. So, he called the carpenter and asked him to make two holes in the door: one big hole for the mother cat and one small hole for the kittens. But the small hole was not used at all, because the kittens always followed their mother and entered through the big hole. Apparently, these holes can still be seen at the university. Sometimes even great minds think in a weird manner.

Niels Bohr

Niels Bohr born on 7th October 1885 in Copenhagen, Denmark and brought up in the same city, made foundational contributions to the understanding of atomic structure and quantum theory for which he was awarded Nobel prize in1922. After his doctorate, he spent several years abroad, including in Manchester and Cambridge. Later on, he returned to Denmark and became the Head of Copenhagen University's Institute for Theoretical Physics (now called Niels Bohr Institute). The Institute became an internationally acclaimed center for the development of quantum physics. Bohr became one of Denmark's most famous Physicist and a prominent figure in 20th century physics.

Lucky Horseshoe on the Door

Niels Bohr used to keep a horse shoe made of a metal on the door of his house. According to European superstitions, the horse shoe fixed to a door is believed to guard the house from evil spirits. A friend of Bohr, on seeing the horseshoe on the door of Bohr's house, asked Bohr whether he subscribed to superstitions. Bohr answered that "the horse shoe works whether or not one believes in its power".

Soccer Player

Bohr was a good and skilled soccer player. He played as a goalkeeper for a well- known and prominent soccer club. During a match against German team, when his team was severally attacked, as a goalkeeper, he was so engrossed in a mathematical problem, he was seen writing equations on the goalpost. A spectator had to shout to warn him of the impending danger or defeat.

A Daring Escape

As his mother was a Jew, Bohr had to flee from Nazi occupied Denmark. Using a fishing boat, first he escaped to Sweden and the proceeded to United States.

Known for breaking Glassware

During his studies at the University of Copenhagen Bohr became famous for clumsiness and causing explosions in the laboratory, particularly for breaking glassware in the chemistry laboratory. Therefore, his chemistry teacher would comment “Oh, that must be Bohr” whenever an explosion was heard from the laboratory.

I hope these anecdotes engage the attention of the readers and make the reading hilarious.

Author

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Why did the math book look sad?

Because it had too many problems.

Why did the computer go to the doctor?

Because it had a virus.

Why did the scarecrow become a successful scientist?

Because he was outstanding in his field.

What did the proton say to the electron?

“Why are you so negative?”

Why did the student bring a compass to science class?

To find their direction in life!

What do you call it when your science teacher lowers your grade?

Bio-degraded

Why are chemists so good at riddles?

They have all the solutions

Astronomers Confirm the Presence of Water on Interstellar Comet 3I/ATLAS

For millions of years, a frozen traveller drifted in silence through the stars, carrying secrets from another world. This summer, that interstellar visitor—now known as **3I/ATLAS**—passed through our solar system, only the third interstellar object known to exist.

When astronomers at **Auburn University** trained NASA's **Neil Gehrels Swift Observatory** on it, they uncovered something incredible: the unmistakable ultraviolet signature of **hydroxyl** (OH), a chemical byproduct of water vapor (H2O).

Unveiling Water from the Stars

Auburn team leader astrophysicist **Zexi Xing** used Swift's ultraviolet vision to detect faint emissions from 3I/ATLAS's coma and thereby confirm that the comet is releasing water. The results revealed that the object releases about 1.36×1027 water molecules per second, or about **40 kilograms per second**. Even more surprisingly, this activity occurred when the comet was almost **three times as distant from the Sun as Earth is**, a region too cold for most comets to lose water.

That degree of activity places 3I/ATLAS in rarefied company. There have been few comets that have exhibited this sort of distant water sublimation, in which the sunlight is so weak that it will not melt ice directly from the surface. The finding means that the water in the comet is instead transported by **small grains of ice** that are shot out into space, where even weak sunlight can vaporize them.

The Ultraviolet Advantage

Swift's **Ultraviolet/Optical Telescope** gave astronomers an edge that ground-based telescopes cannot: the ability to see through the Earth's atmosphere, which blankets most ultraviolet light and hides these delicate signals from the eye.

While in orbit, Swift observed two sets of ultraviolet images of 3I/ATLAS during the summer of 2025—once in late July and again mid-August. During the time between the two observations, the hydroxyl signal nearly doubled, demonstrating that water production increased dramatically as the comet neared the Sun.

Because the spacecraft can't aim at moving targets, scientists used a ploy called **motion correction**, slicing the data into 30-second pieces to avoid blurring the images with the comet's light. After stacking the exposures together, the scientists observed a foggy envelope of gas around the nucleus—a clear sign that water was being released into space.

Measuring the Flow

Determining how much water was being emitted took a process of steps. The researchers started by approximating how many hydroxyl molecules are within a 10-arcsecond radius of the nucleus and found about 2.2×1030 molecules in July and 4.2×1030 as of mid-August. Based on sunlight-driven models, they estimated how quickly water was breaking up, and that told them to estimate their final production rate.

To be accurate, the scientists accounted for the manner in which the dust on the comet scatters sunlight, adjusted for what astronomers call "**reddening**." Without that adjustment, faint ultraviolet radiation could be mistaken for scattered light instead of actual chemical action.

If water found was actually coming directly from the surface of the comet, then at least **7.8 square km—or over 8%—of its surface must be actively emitting vapor**. That is incredibly high for a body whose nucleus radius is about 2.8 km. The majority of comets in our solar system only have 3–5% of their surface active at one time or another. That amount of activity indicates that 3I/ATLAS could have an **atypically ice-dense surface** or that it's shedding volatile dust grains that continue evaporating after being expelled.

Interstellar Visitors Compared

This is a major breakthrough for astronomers studying interstellar travellers.

- The first guest, **1I/'Oumuamua**, was rocky and dry, devoid of any signs of gas activity.
- The second one, **2I/Borisov**, released water and carbon monoxide in roughly equal quantities before later going back to a carbon monoxide–dominant mixture.
- Now, **3I/ATLAS** has revised the script again, with **intense water activity** away from the Sun and very little sign of other volatile gases.

Infrared measurements also revealed frozen grains that orbited around it, with the suggestion that much of its water is derived from suspended material rather than the solid core. By comparing the infrared and ultraviolet data, scientists were able to validate that the emissions were from water—not nickel or carbon monoxide, which can mimic similar signs.

Each interstellar comet possesses a tale of where it was formed. 'Oumuamua was rocky and dry, Borisov was carbon-rich, and ATLAS is **water-active at never-before-seen distances**. Such diversity indicates that planetary systems other than our own Sun form comets under vastly different conditions.

Dennis Bodewits, Auburn physics professor and co-author of the study, simplified it thus: "When we see water—or even its faint ultraviolet echo—coming from an interstellar comet, we're reading a message from outside our planetary system. It says the **chemical building blocks for life are not unique to our own**."

A Window into Planet Formation

The discovery also reveals how comets can transport water and organic molecules between galaxies. If bodies like 3I/ATLAS can endure frozen water for extended interstellar missions, they might be the delivery vehicles for the **ingredients of life** among stellar systems. The comet's unusual chemistry—**water-rich but cyanogen-poor (CN)—could mean that it formed out of material within a carbon-deprived environment near a youthful, metal-poor star.**

As Xing noted, "Each interstellar comet that has come by so far has been a surprise. 'Oumuamua was dehydrated, Borisov was carbon monoxide-rich, and now ATLAS is losing water at a distance where we didn't expect it. Each one is rewriting what we thought we knew about the formation of planets and comets around stars."

3I/ATLAS had not been visible since but will return after mid-November and give astronomers another chance to observe how its activity changes near the Sun. Continuing observations with space telescopes could decide whether its water activity remains static or other gases take center stage when solar heating intensifies.

Practical Implications of the Research

Findings such as these open our eyes to the ways water—and perhaps the building blocks of life—move through the universe.

By establishing that interstellar bodies can **preserve ice on timescales that stretch for millions of millions of years**, the study gives us a deeper understanding of how solar systems begin and evolve.

It adds weight to the possibility that **comets are cosmic messengers**, delivering water and organic compounds from one nascent world to the next, potentially giving life a foothold in more than one corner of the universe.

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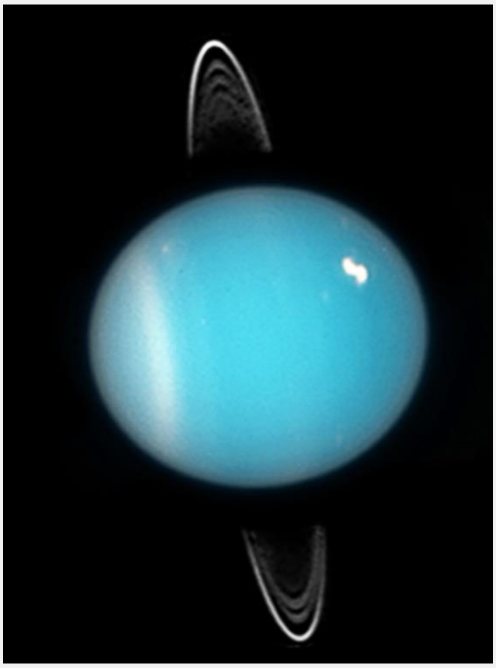
ಯುರೇನಸ್

ಯುರೇನಸ್ ಸೂರ್ಯನಿಂದ ಏಳನೇ ಗ್ರಹವಾಗಿದ್ದು, ವಿಲಿಯಂ ಹರ್ಷಿಲ್ 1780ರಲ್ಲಿ ಕಂಡುಹಿಡಿದರು. ಇದು ದೂರದರ್ಶಕದಿಂದ ಕಂಡುಹಿಡಿಯಲಾದ ಮೊದಲನೇ ಗ್ರಹವಾಗಿದೆ ಮತ್ತು ಸೂರ್ಯಮಂಡಲದಲ್ಲಿ ಮೂರನೇ ದೊಡ್ಡ ಗ್ರಹ, ಆದರೆ ದ್ರವ್ಯರಾಶಿಯಲ್ಲಿ ನಾಲ್ಕನೇ ಅತಿ ದೊಡ್ಡ ಗ್ರಹವಾಗಿದೆ. ಸೂರ್ಯನಿಂದ 19 ಎ ಯು ಅಂದರೆ 2.9 ಶತಕೋಟಿ ಕಿ.ಮೀ. ದೂರದಲ್ಲಿದೆ. (ಒಂದು ಎ ಯು ಎಂದರೆ ಸೂರ್ಯನಿಗೂ ಮತ್ತು ಭೂಮಿಗೂ ಇರುವ ಸರಾಸರಿ ದೂರ=150 ದಶಲಕ್ಷ ಕಿ.ಮೀ.). ಇದು ಸೂರ್ಯಮಂಡಲದ ಹಿಮಾವೃತ ದೈತ್ಯವಾಗಿದ್ದು, ಸೌರಮಂಡಲದಲ್ಲೇ ಅತ್ಯಂತ ತಂಪು ಗ್ರಹವೆನಿಸಿದೆ. ಯುರೇನಸ್ ಎಷ್ಟು ದೊಡ್ಡದಾಗಿದೆಯೆಂದರೆ ಅದರೊಳಗೆ 63 ಭೂಮಿಯನ್ನು ಹಿಡಿಸುತ್ತದೆ. ಇದು ಭೂಮಿಯ ದ್ರವ್ಯರಾಶಿಯ 14.5ರಷ್ಟು ಇದೆ, ಗುರುತ್ವಾಕರ್ಷಣೆಯು 8.7 ಮೀ./ಸೆಕೆಂಡ್/ಸೆಕೆಂಡ್. ಯುರೇನಸ್‌ನ ಸಾಂದ್ರತೆಯು ಕಡಿಮೆ ಇರುವುದರಿಂದ, ಮೇಲ್ಮೈ ಗುರುತ್ವಾಕರ್ಷಣೆಯೂ ಕಡಮೆ ಇದೆ. ಇದು 51,118 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದ್ದು ಭೂಮಿಯ ಸುಮಾರು ನಾಲ್ಕು ಪಟ್ಟು ಇದೆ. ಗ್ರೀಕ್ ಆಕಾಶ ದೇವತೆಯ ಹೆಸರಾದ ಯುರೇನಸ್‌ಅನ್ನು ಕೆಲವು ಹಿಂದೂ ಪಂಡಿತರು ಅರುಣ ಎಂದು ಕರೆದಿದ್ದಾರೆ. ಹಿಂದೂ ಪುರಾಣಗಳಲ್ಲಿ ಆಧುನಿಕ ಜ್ಯೋತಿಷ್ಯದ ಕೆಲವು ಪ್ರವೃತ್ತಿಗಳಲ್ಲಿ ಯುರೇನಸ್‌ಅನ್ನು ರಾಹು ಎಂದು ಪರಿಗಣಿಸುತ್ತಾರೆ.



ಚಿತ್ರ 1 ಯುರೇನಸ್‌ನ ಕಕ್ಷೆಯು ಭೂಮಧ್ಯರೇಖೆಗೆ 97 ಡಿಗ್ರಿ ಕಕ್ಷೆಯ ಓರೆಯಾಗಿರುವುದು

ಯುರೇನಸ್‌ನ ಕಕ್ಷೆ ಮತ್ತು ಭ್ರಮಣ: ಯುರೇನಸ್ ಮತ್ತು ವೀನಸ್ ಮಾತ್ರ ಉಳಿದ ಗ್ರಹಗಳಿಗಿಂತ ವಿರುದ್ಧ ದಿಕ್ಕಿನಲ್ಲಿ ಅಂದರೆ ಪ್ರದಕ್ಷಿಣಾಕಾರದಲ್ಲಿ ಭ್ರಮಣ ಮಾಡುತ್ತವೆ. ತನ್ನ ಅಕ್ಷದಮೇಲೆ ಭ್ರಮಣ ಮಾಡಲು ಯುರೇನಸ್‌ಗೆ 17 ಭೂಗಂಟೆಗಳು ಬೇಕು, ಅಂದರೆ ಅದಕ್ಕೆ ಒಂದು ದಿನ. ತನ್ನ ಕಕ್ಷೆಯಲ್ಲಿ ಸೂರ್ಯನ ಸುತ್ತ ಒಂದು ಸುತ್ತು ಬರಲು ಯುರೇನಸ್ 84 ಭೂವರ್ಷಗಳನ್ನು ತೆಗೆದುಕೊಳ್ಳುತ್ತದೆ. ಇದರ ಭೂಮಧ್ಯ ರೇಖೆಯು ಭ್ರಮಣದ ಅಕ್ಷಕ್ಕೆ 97 ಡಿಗ್ರಿ ಓರೆಯಾಗಿದ್ದು, ತೀವ್ರವಾಗಿ ವಾಲಿದೆ. ಸೂರ್ಯಮಂಡಲದಲ್ಲಿ ಈ ಒಂದು ಗ್ರಹ ಮಾತ್ರ ಹೀಗೆ ಸಮಭಾಜಕಕ್ಕೆ, ಅಕ್ಷದ ಓರೆಯು ಬಹುತೇಕ ಲಂಬವಾಗಿದೆ. ಆದ್ದರಿಂದ ಸೂರ್ಯನ ಸುತ್ತ

ಸುತ್ತಲು ಭೂಮಿಯಂತೆ ಬಹಳ ಮಟ್ಟಿಗೆ ನೇರವಾಗಿರದೆ (ಭೂಅಕ್ಷವು 23 ಡಿಗ್ರಿ ಮಾತ್ರ ವಾಲಿದೆ) 97 ಡಿಗ್ರಿ ವಾಲಿಕೊಂಡು ಸುತ್ತುತ್ತಿದೆ (ಚಿತ್ರ 1). ಇದರಿಂದಾಗಿ **ಯುರೇನಸ್, ಸೂರ್ಯನನ್ನು ಗಾಡಿಯ ಚಕ್ರದಂತೆ ಉರುಳಿಗೊಂಡು ಸುತ್ತುತ್ತಿದೆ ಎನ್ನುತ್ತಾರೆ**. ಹೀಗೆ ಹೆಚ್ಚಿಗೆ ವಾಲಿರುವುದರಿಂದ ಯುರೇನಸ್‌ನಲ್ಲಿ ದೀರ್ಘಕಾಲದ ಋತುಗಳಿವೆ. ಧ್ರುವಗಳಲ್ಲಿ ಒಟ್ಟಾರೆ 42 ವರ್ಷಗಳ ಬೆಳಕು ಮತ್ತು 42 ವರ್ಷಗಳ ಕತ್ತಲೆ ಇರುತ್ತದೆ. ಇದು ಪರ್ಯಾಯವಾಗಿ ಬದಲಾವಣೆ ಹೊಂದುತ್ತಿವೆ.

ಭೌತಿಕ ಲಕ್ಷಣಗಳು: ಯುರೇನಸ್ ಒಳಭಾಗದಲ್ಲಿನ ಕೇಂದ್ರವು ಅತಿ ಉಷ್ಣತೆಯಿಂದ ಅಂದರೆ ಸುಮಾರು 5000 ಡಿಗ್ರಿ ಸೆಲ್ಸಿಯಸ್‌ಗೂ ಹೆಚ್ಚು ಇದ್ದು ಸಾಂದ್ರವಾದ ಸಿಲಿಕೇಟ್ ಬಂಡೆಗಳಿಂದ ಕೂಡಿದೆ. ನಂತರದ ಅದರ ಹೊದಿಕೆಯ ಭಾಗವು ನೀರು, ಅಮೋನಿಯಾ, ಮೀಥೇನ್ ಮತ್ತು ಇತರ ಬಾಷ್ಪಶೀಲ ವಸ್ತುಗಳಿಂದ ಕೂಡಿದ್ದು, ಇಲ್ಲೂ ಸುಮಾರು 5000 ಡಿಗ್ರಿ ಸೆಲ್ಸಿಯಸ್ ಉಷ್ಣತೆ ಮತ್ತು ಹೆಚ್ಚು ಒತ್ತಡದಿಂದ ಕೂಡಿದೆ. ಇದನ್ನು 'ನೀರು–ಅಮೋನಿಯಾ ಸಮುದ್ರ' ಎನ್ನಲಾಗಿದೆ. ಅತಿಯಾದ ಉಷ್ಣತೆ ಮತ್ತು ಒತ್ತಡದಿಂದ ಅಲ್ಲಿನ ಮೀಥೇನ್ ಮಾಲಿಕ್ಯೂಲ್‌ಗಳು ಒಡೆದು ಅದರಲ್ಲಿನ ಇಂಗಾಲದ ಪರಮಾಣುಗಳು ಹರಳೀಕರಣಗೊಂಡು ವಜ್ರವಾಗುತ್ತವೆ. ದ್ರವ ಸಮುದ್ರದ ಮೇಲೆ ವಜ್ರದ ಮಂಜುಗಡ್ಡೆಯ ಭಾರಿ ತುಂಡುಗಳು ಇವೆಯೆಂದು ಅನೇಕ ಖಗೋಳವಿಜ್ಞಾನಿಗಳ ಸಿದ್ಧಾಂತ. ಯುರೇನಸ್ ಸೂರ್ಯನ ಬೆಳಕಿನಲ್ಲಿರುವ ಕೆಂಪು ಬಣ್ಣವನ್ನು ಹೀರಿಕೊಂಡು ನೀಲಿ–ಹಸಿರು ಬೆಳಕನ್ನು ಪ್ರತಿಫಲಿಸುವುದರಿಂದ, ಯುರೇನಸ್ ಹಸಿರು ಮಿಶ್ರಿತ ನೀಲಿ ಬಣ್ಣದಲ್ಲಿ ಕಾಣುತ್ತದೆ.

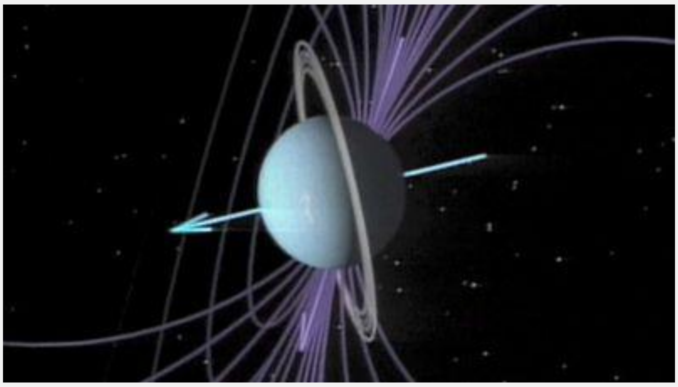
ವಾತಾವರಣ: ಯುರೇನಸ್‌ನ ವಾತಾವರಣವು ಪ್ರತಿಶತ 83 ಭಾಗ ಜಲಜನಕ, ಸ್ವಲ್ಪ ಭಾಗ ಹೀಲಿಯಂ, ನೀರಿನಿಂದ ಕೂಡಿದ ಮಂಜುಗಡ್ಡೆ, ಅಮೋನಿಯಾ, ಮತ್ತು ಮೀಥೇನ್‌ಗಳಿಂದ ಕೂಡಿದೆ. ಇವು ವಾತಾವರಣದ ಪದರಗಳಲ್ಲಿ, ವಸ್ತುವಿನ ಸೂಪರ್ ಕ್ರಿಟಿಕಲ್ ಸ್ಥಿತಿಯನ್ನು ತಲುಪಿ (ಸೂಪರ್ ಕ್ರಿಟಿಕಲ್ ಸ್ಥಿತಿ ಅಂದರೆ ಒಂದು ನಿರ್ದಿಷ್ಟ ಉಷ್ಣಾಂಶ ಹಾಗೂ ನಿರ್ದಿಷ್ಟ ಒತ್ತಡವನ್ನು ಮೀರಿದಾಗ ದ್ರವ ಮತ್ತು ಅನಿಲದ ನಡುವೆ ವ್ಯತ್ಯಾಸ ಕಾಣಿಸದು) ಸಂಕೀರ್ಣ ಪದರಗಳ ಮೋಡದ ರಚನೆಯನ್ನು ಹೊಂದಿದೆ. ಯುರೇನಸ್‌ನ ಮೇಲ್ಮೈನಲ್ಲಿ ನೀಲಿ–ಬಿಳಿ ಮೋಡಗಳು ಮೀಥೇನ್‌ನಿಂದ ಕೂಡಿವೆ. ಮಧ್ಯದ ಮೋಡದಲ್ಲಿ ಅಮೋನಿಯಾ ಮತ್ತು ಹೈಡ್ರೋಸಲ್ಫೈಡ್ ಅನಿಲಗಳಿಂದ ಕೂಡಿದೆ. ಕೆಳಗಿನ ಮೋಡವು ಜಲಜನಕ ಮತ್ತು ಹೀಲಿಯಂನಿಂದ ರೂಪುಗೊಂಡಿದೆ. ಈ ಭಾಗದಲ್ಲಿ ಅದರ ಕನಿಷ್ಠ ಉಷ್ಣಾಂಶವು –224 ಡಿಗ್ರಿ ಸೆಲ್ಸಿಯಸ್ (–371 ಡಿಗ್ರಿ ಫ್ಯಾರನ್‌ಹೀಟ್) ತಲುಪಿ ಅದು ಸೂರ್ಯಮಂಡಲದಲ್ಲೇ ಅತಿ ಕಡಿಮೆ ಉಷ್ಣಾಂಶವೆನಿಸಿದೆ. ಯುರೇನಸ್ ವಾತಾವರಣದಲ್ಲಿ ಕೆಲವು ಮೋಡಗಳ ಪದರಗಳು ಹಠಾತ್ ಚಲನೆಯಲ್ಲಿ ಇರುತ್ತವೆ.

ಯುರೇನಸ್‌ನ ಉಂಗುರಗಳು: ಯುರೇನಸ್ ಗ್ರಹದ ಸುತ್ತ ಮುಸುಕಾದ ಮತ್ತು **ತೆಳುವಾದ ಹದಿಮೂರು ಉಂಗುರ**ಗಳ ವ್ಯವಸ್ಥೆಯನ್ನು ನೋಡಬಹುದು. ಇದನ್ನು 1977ರಲ್ಲಿ ಜೇಮ್ಸ್ ಎಲ್ ಎಲಿಯಟ್ ಮತ್ತು ಸಂಗಡಿಗರಿಂದ ಕಂಡುಹಿಡಿಯಲಾಯಿತು. ಕೆಲವು ಹತ್ತು ಮೀ.ಗಳವರೆಗೂ ವ್ಯಾಸವುಳ್ಳ ತುಣುಕುಗಳಿಂದ ಕೂಡಿವೆ. 1986ರಲ್ಲಿ ವಾಯೇಜರ್–2 ಬಾಹ್ಯಾಕಾಶ ನೌಕೆಯು ಉಂಗುರಗಳ ಚಿತ್ರಣಗಳನ್ನು ಸೆರೆಹಿಡಿದು ಹೆಚ್ಚಿನ ವಿವರಣೆ ನೀಡಿತು. ನಂತರ 2005ರಲ್ಲಿ ಹಬಲ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕದಲ್ಲಿ, ಜೇಮ್ಸ್ ಎಲ್ ಎಲಿಯಟ್ ತಂಡದವರಿಂದ ಹದಿಮೂರು ಉಂಗುರಗಳ ಚಿತ್ರಣಗಳನ್ನು ಸೆರೆಹಿಡಿಯಲಾಯಿತು. ಹೊರಗಿನ ಉಂಗುರಗಳು ಯುರೇನಸ್‌ನಿಂದ ಹೆಚ್ಚು ದೂರವಿದ್ದು ಮೊದಲಿನವುಗಳಿಗಿಂತ ಎರಡರಷ್ಟು ವ್ಯಾಸವನ್ನು ಹೊಂದಿವೆ. ಅವುಗಳಲ್ಲಿ ಒಂದು ಉಂಗುರವು ವರ್ಣಪಟಲದಲ್ಲಿ ನೀಲಿಯಾಗಿಯೂ ಮತ್ತೊಂದು ಕೆಂಪಾಗಿಯೂ, ಉಳಿದ ಉಂಗುರಗಳು ಬೂದು ಬಣ್ಣದಲ್ಲಿ ಕಾಣುತ್ತವೆ. ಈ ಉಂಗುರಗಳು ಅನೇಕ ಅಂತರಿಕ ಚಂದಿರರ ಹತ್ತಿರ ಇದ್ದು ಅವುಗಳು ಉಂಗುರಗಳನ್ನು ಅನುಸರಿಸುತ್ತವೆ.

ಯುರೇನಸ್ ಉಂಗುರಗಳಿಗೆ ಗ್ರೀಕ್ ಅಕ್ಷರಗಳ ಮತ್ತು ಸಂಖ್ಯೆಗಳ ಹೆಸರುಗಳನ್ನು ಕೊಡಲಾಗಿದೆ. ಅವುಗಳೆಂದರೆ **ಝೀಟಾ, 6ನೇ ಉಂಗುರ, 5ನೇ ಉಂಗುರ, 4ನೇ ಉಂಗುರ, ಆಲ್ಫಾ, ಬೀಟಾ, ಈಟಾ, ಗಾಮಾ, ಡೆಲ್ಟಾ, ಲ್ಯಾಮ್ಡಾ, ಎಪ್ಸಿಲಾನ್, ನ್ಯೂ ಮತ್ತು ಮ್ಯೂ** (ಚಿತ್ರ 3). ಇವುಗಳಲ್ಲಿ ಎಪ್ಸಿಲಾನ್ ಉಂಗುರ ಅತಿ ದಟ್ಟ ಹಾಗೂ ಪ್ರಮುಖವಾದದ್ದು. ನ್ಯೂ ಮತ್ತು ಮ್ಯೂ ಉಂಗುರಗಳು ಸ್ವಲ್ಪ ದೂರದಲ್ಲಿದ್ದು ಧೂಳು ತುಂಬಿವೆ. ಇವೆಲ್ಲವೂ ಅಂತರಿಕ ಚಂದಿರರುಗಳ ಸಮೀಪದಲ್ಲೇ ಸೇರಿಕೊಂಡಿವೆ.

ಯುರೇನಸ್‌ನ ಉಂಗುರಗಳು ನೀರಿನಹಿಮಗಡ್ಡೆ ಹಾಗೂ ಕಾರ್ಬನ್‌ಯುಕ್ತ ಕಣಗಳಿಂದ ನಿರ್ಮಾಣವಾಗಿವೆ. ಉಂಗುರಗಳಲ್ಲಿ ಸಣ್ಣ ಧೂಳಿನಿಂದ ಹಿಡಿದು 10 ಮೀಟರ್‌ಗಳ ಬಂಡೆಗಳಷ್ಟು ದೊಡ್ಡ ಪ್ರಮಾಣದ ಕಾಯಗಳಿವೆ. ಆ ಉಂಗುರಗಳ ಗಾತ್ರವು ಕೆಲವು ಕಿ.ಮೀ.ನಿಂದ 100 ಕಿ.ಮೀ.ವರೆಗೆ ಇವೆ. ಈ ಉಂಗುರಗಳು 2% ಸೂರ್ಯನ ಬೆಳಕನ್ನು ಮಾತ್ರ ಪ್ರತಿಫಲಿಸುತ್ತವೆಯಾದ್ದರಿಂದ ಬರಿಗಣ್ಣುಗಳಿಂದ ನೋಡಲಾಗುವುದಿಲ್ಲ.

ಯುರಾನಸ್‌ನ ಕಾಂತಕ್ಷೇತ್ರ: ಯುರೇನಸ್‌ನಲ್ಲಿನ ಕಾಂತಕ್ಷೇತ್ರವು, ವಾಯೇಜರ್–2 ಬಾಹ್ಯಾಕಾಶ ನೌಕೆಯು ಸಮೀಪ ಬರುವವರೆಗೂ ತಿಳಿದಿರಲಿಲ್ಲ. ಇದರ ಕಾಂತಕ್ಷೇತ್ರವು ಭೂಮಿಯ ಕಾಂತಕ್ಷೇತ್ರಕ್ಕೆ ಹೋಲಿಸಬಹುದು. ಯುರೇನಸ್ ಗ್ರಹದ ಮಧ್ಯದಲ್ಲಿ ನೀರು ವಿದ್ಯುತ್‌ವಾಹಕವಾಗಲು ಸಾಕಷ್ಟು ಒತ್ತಡವಿರುವುದರಿಂದ ಅಲ್ಲಿ ಕಾಂತಕ್ಷೇತ್ರವು ಉತ್ಪತ್ತಿಯಾಗುತ್ತದೆ ಎಂದು ತಿಳಿದುಬಂದಿದೆ. ಇದರ ಕಾಂತಕ್ಷೇತ್ರದ ಅಕ್ಷವು ಭ್ರಮಣದ ಅಕ್ಷದಿಂದ 60 ಡಿಗ್ರಿ ಬಾಗಿದೆ (ಚಿತ್ರ 2). ಇದರಿಂದಾಗಿ ಯುರೇನಸ್‌ನ ಉತ್ತರ ಗೋಳಾರ್ಧದಲ್ಲಿ ಕಾಂತಕ್ಷೇತ್ರವು ದಕ್ಷಿಣಾರ್ಧ ಗೋಳಕ್ಕಿಂತ 10 ಪಟ್ಟು ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ.



ಚಿತ್ರ 2 ಯುರಾನಸ್‌ನ ಕಾಂತಕ್ಷೇತ್ರ

ಯುರೇನಸ್‌ನ ವಿಕಿರಣ ಪಟ್ಟೆಗಳು ಶನಿಗ್ರಹದಂತೆಯೇ ತೀವ್ರತೆಯನ್ನು ಹೊಂದಿದೆ. ಈ ವಿಕಿರಣಗಳು ಚಂದ್ರರು ಮತ್ತು ಉಂಗುರ ಕಣಗಳ ಹಿಮಾವೃತ ಮೇಲ್ಮೈಗಳಲ್ಲಿ ಬಿದ್ದು ಅವುಗಳಲ್ಲಿನ ಮೀಥೇನ್‌ಅನ್ನು ಕಪ್ಪಾಗಿಸುತ್ತದೆ ಎಂದು ತಿಳಿದುಬಂದಿದೆ. ಆದ್ದರಿಂದಲೇ ಯುರೇನಸ್‌ನ ಚಂದಿರರು ಮತ್ತು ಉಂಗುರಗಳು ಬೂದು ಬಣ್ಣವನ್ನು ಹೊಂದಿರಬಹುದೆಂದು ಊಹಿಸಲಾಗಿದೆ.

ಯುರೇನಸ್ ತನ್ನ ಧ್ರುವದ ಸುತ್ತಲೂ ಹೆಚ್ಚು ಪ್ರಮಾಣದಲ್ಲಿ ನೇರಳಾತೀತ ಬೆಳಕನ್ನು ಹೊರಸೂಸುತ್ತದೆ ಎಂದು ಕಂಡುಬಂದಿದೆ. ಈ ವಿದ್ಯಮಾನವನ್ನು ಎಲಕ್ಟ್ರೋಗ್ಲೋ ಎಂದು ಕರೆಯುತ್ತಾರೆ. ಈ ಗ್ರಹದ ವಾತಾವರಣದ ಸರಾಸರಿ ಉಷ್ಣತೆಯು ಸುಮಾರು 49 ಕೆಲ್ವಿನ್ ಅಥವಾ –224 ಸೆಲ್ಸಿಯಸ್ ಇದ್ದು ಇದರ ಮೋಡದ ಮೇಲ್ಭಾಗದಲ್ಲಿ ಬಹುತೇಕ ಒಂದೇ ಉಷ್ಣತೆಯನ್ನು ತೋರಿಸುತ್ತದೆ.

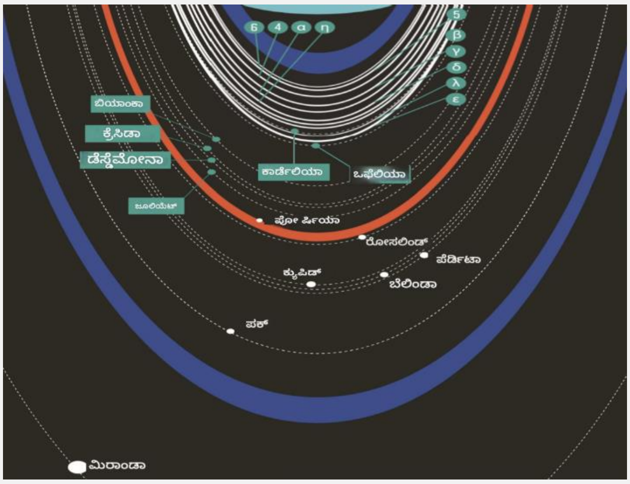
ಯುರೇನಸ್‌ನ ಚಂದಿರಗಳು

ಯುರೇನಸ್‌ಅನ್ನು 28 ಚಂದಿರರು ಸುತ್ತುತ್ತಿದ್ದಾರೆ. ಈ ಚಂದಿರರನ್ನು ಸಾಹಿತ್ಯಿಕ ಚಂದಿರರು (*Literary Moons*) ಎಂದು ಕರೆಯುತ್ತಾರೆ. ಏಕೆಂದರೆ ಅವು ಶೇಕ್ಸ್‌ಪಿಯರ್ ನಾಟಕದ ಪಾತ್ರಗಳ ಹೆಸರುಗಳಾಗಿವೆ. ಕೆಲವು ಮಾತ್ರ ಅಲೆಕ್ಸಾಂಡರ್ ಪೋಪ್‌ನ ಗ್ರಂಥಗಳದಾಗಿವೆ.

ಯುರೇನಸ್‌ನ ಮುಖ್ಯವಾದ ಐದು ಚಂದಿರರೆಂದರೆ ಮಿರಾಂಡ, ಏರಿಯಲ್, ಅಂಬ್ರಿಯಲ್ ಟೈಟಾನಿಯಾ ಮತ್ತು ಒಬಿರಾನ್. ಟೈಟಾನಿಯಾ ಮತ್ತು ಒಬಿರಾನ್‌ಗಳು ಯುರೇನಸ್‌ನ ದೊಡ್ಡ ಚಂದಿರರುಗಳಾಗಿದ್ದು, 1787ರಲ್ಲಿ ವಿಲಿಯಂ ಹರ್ಷಿಲ್‌ರಿಂದ ಕಂಡುಹಿಡಿಯಲ್ಪಟ್ಟಿತು. 1851ರಲ್ಲಿ ವಿಲಿಯಂ ಲಾಸೆಲ್ ಎಂಬ ಖಗೋಳವಿಜ್ಞಾನಿಯು ಏರಿಯಲ್ ಮತ್ತು ಅಂಬ್ರಿಯಲ್ ಚಂದಿರರನ್ನು, 1948ರಲ್ಲಿ ಜೆರಾಲ್ಡ್ ಕೂಪಿಯರ್ ಖಗೋಳವಿಜ್ಞಾನಿ ಮಿರಾಂಡಾ ಚಂದಿರನನ್ನು ಕಂಡುಹಿಡಿದರು. 1986ರಲ್ಲಿ ವಾಯೇಜರ್-2 ನೌಕೆಯು ಯುರೇನಸ್ ಸಮೀಪ ಬಂದಾಗ 26ರಿಂದ 154 ಕಿಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿರುವ ಯುರೇನಸ್ ಸಮೀಪದ 10 ಚಂದಿರರನ್ನು ಕಂಡುಹಿಡಿಯಿತು. ಅವೇ ಜೂಲಿಯಟ್, ಪಕ್, ಕಾರ್ಡಿಲಿಯಾ, ಒಪಿಲಿಯಾ, ಬಿಯಾಂಕಾ, ಡೆಸ್ಡಿಮೋನಾ, ಪೋರ್ಷಿಯಾ, ರೊಸಾಲಿಂಡ್, ಕ್ರೆಸಿಡಿಯಾ, ಮತ್ತು ಬಿಲಿಂಡಾ ಎಂಬ ಚಿಕ್ಕ ಅಂತರಿಕ ಚಂದಿರರು.

ಯುರೇನಸ್ ಚಂದಿರರನ್ನು ಮೂರು ವಿಧಗಳಿವೆ. ಅವೆಂದರೆ 14 ಅಂತರಿಕ ಚಂದಿರರು (*Inner moons*). 5 ಪ್ರಧಾನ ಚಂದಿರರು (*Major moons*), 9 ಅನಿಯಮಿತ ಚಂದಿರರು (*Irregular moons*) .

ಹದಿನಾಲ್ಕು ಅಂತರಿಕ ಚಂದಿರರು (*Inner moons*) ಮಿರಾಂಡಾ ಚಂದಿರನ ಒಳಕಕ್ಷೆಯೊಳಗೆ ಸುತ್ತುತ್ತಿವೆ. ಇವು ಕಾರ್ಡೇಲಿಯಾ, ಒಫೇಲಿಯಾ, ಬಿಯಾಂಕಾ, ಕ್ರೆಸಿಡಾ, ಡೆಸ್ಡಿಮೋನಾ, ಪೋರ್ಷಿಯಾ, ಜೂಲಿಯಟ್, ಕ್ಯುಪಿಡ್, ಬೆಲಿಂಡಾ, ರೋಸಲಿಂಡ್, ಕ್ಯುಪಿಡ್, ಪರ್ಡಿಟಾ, ಪಕ್ ಮತ್ತು ಮಾಬ್ (ಚಿತ್ರ 3). ಈ ಅಂತರಿಕ ಚಂದಿರರು ಯುರೇನೆಸ್‌ನ ಉಂಗುರಗಳಿಗೆ ಸಂಪರ್ಕಹೊಂದಿವೆ. ಯುರೇನಸ್‌ನ 'ಶಪರ್ಡ್ ಮೂನ್ಸ್' ಗಳಾದ ಕಾರ್ಡೇಲಿಯಾ ಮತ್ತು ಒಫೆಲಿಯಾಗಳು ಯುರೇನಸ್‌ನ ಎಪ್ಸಿಲಾನ್ ಉಂಗುರವನ್ನು ಅನುಸರಿಸುತ್ತವೆ. ಶಪರ್ಡ್ ಮೂನ್ಸ್ ಅಂದರೆ ಅವು ಗ್ರಹದ ಸುತ್ತ ಉಂಗುರಗಳ ಹತ್ತಿರ ತಿರುಗುವ ಚಿಕ್ಕ ಚಂದಿರರಾಗಿದ್ದು, ಉಂಗುರಕ್ಕೆ ಸೀಮಿತಗೊಳಿಸಲು ತಮ್ಮ ಗುರುತ್ವಾಕರ್ಷಣೆಯನ್ನು ಬಳಸುತ್ತವೆ. ಪಕ್ ಚಂದಿರನು ಅಂತರಿಕ ಚಂದಿರರಲ್ಲಿ ಅತಿ ದೊಡ್ಡದು. ವಾಯೇಜರ್-2 ಇದರ ಚಿತ್ರಣವನ್ನು ಭೂಮಿಗೆ ಕಳುಹಿಸಿದೆ. ಪಕ್ ಮತ್ತು ಮಾಬ್ ಅತ್ಯಂತ ಹೊರಗಿನ ಅಂತರಿಕ ಚಂದಿರರು. ಇವು ನೀರಿನ ಮಂಜುಗಡ್ಡೆಯ ವಿಕಿರಣದಿಂದ ಸಂಸ್ಕರಣಗೊಂಡ ಆರ್ಗ್ಯಾನಿಕ್ ವಸ್ತುಗಳಿಂದ ಕೂಡಿರುವುದರಿಂದ ಕಪ್ಪುಬಣ್ಣದಲ್ಲಿ ಕಾಣುತ್ತವೆ.



ಚಿತ್ರ 3 ಯುರೇನಸ್‌ನ ಅಂತರಿಕ ಚಂದಿರರು

ಕಾರ್ಡೇಲಿಯಾವನ್ನು 1986ರಲ್ಲಿ ವಾಯೇಜರ್–2 ಪತ್ತೆ ಮಾಡಿದೆ. ಇದರ ವ್ಯಾಸವು 42 ಕಿ.ಮೀ. ಇದ್ದು, ಯುರೇನಸ್‌ಅನ್ನು ಅತಿ ಹತ್ತಿರದಲ್ಲಿ ಸುತ್ತುತ್ತಿದೆ. ಇದು ಯುರೇನಸ್‌ನ ಎಪ್ಸಿಲಾನ್ ಉಂಗುರವನ್ನು ಸ್ಥಿರವಾಗಿ ಇರಿಸಲು ಸಹಾಯಮಾಡುತ್ತದೆ. ಕಾರ್ಡೇಲಿಯಾ ಶೇಕ್ಸ್‌ಪಿಯರ್‌ನ 'ಕಿಂಗ್ ಲಿಯರ್' ನಾಟಕದ ಪಾತ್ರದ ಹೆಸರಾಗಿದೆ.

ಒಫಿಲಿಯಾವನ್ನೂ 1986ರಲ್ಲಿ ವಾಯೇಜರ್–2 ಪತ್ತೆ ಮಾಡಿದ್ದು, ಸುಮಾರು 43 ಕಿ.ಮೀ. ವ್ಯಾಸವಿರುವ ಇದು ಕಾರ್ಡೇಲಿಯಾದ ಅನಂತರದ ಕಕ್ಷೆಯಲ್ಲಿ ಯುರೇನಸ್‌ನನ್ನು ಸುತ್ತುತ್ತಿದೆ. ಇದೂ ಸಹ ಎಪ್ಸಿಲಾನ್ ಉಂಗುರವನ್ನು ಸ್ಥಿರವಾಗಿ ಇರಿಸಲು ಸಹಾಯಮಾಡುತ್ತದೆ. ಒಫಿಲಿಯಾ ಶೇಕ್ಸ್‌ಪಿಯರನ 'ಹ್ಯಾಮ್ಲೆಟ್' ನಾಟಕದ ದುರಂತ ನಾಯಕಿಯ ಹೆಸರಾಗಿದ್ದು, ಪ್ರಕಾಶಮಾನವಾದ ಚಂದಿರನಾಗಿದೆ.

ಬಿಯಾಂಕಾ 1986ರಲ್ಲಿ ವಾಯೇಜರ್–2ರಿಂದ ಪತ್ತೆಯಾಗಿದೆ. ಇದು 52 ಕಿ.ಮೀ. ವ್ಯಾಸವಿದ್ದು, ಮೇಲ್ಮೈ ಕಪ್ಪುಬಣ್ಣದಿಂದ ಇರುವುದರಿಂದ ಬೆಳಕನ್ನು ಕಡಿಮೆ ಪ್ರತಿಫಲಿಸುತ್ತದೆ. ಇದು ಶೇಕ್ಸ್‌ಪಿಯರನ 'ದ ಟೇಮಿಂಗ್ ಆಫ್ ದ ಶ್ರ್ಯೂ' ನಾಟಕದಲ್ಲಿ ಬರುವ ಪಾತ್ರದ ಹೆಸರು.

ಕ್ರೆಸಿಡಾ ಸುಮಾರು 80 ಕಿ.ಮೀ. ವ್ಯಾಸವಿದ್ದು, ಬೆಳಕನ್ನು ಪ್ರತಿಬಿಂಬಿಸುವ ಚಂದಿರರಲ್ಲಿ ಒಂದಾಗಿದೆ. ಇದು ಶೇಕ್ಸ್‌ಪಿಯರ್‌ನ 'ಟ್ರಯ್‌ಲಸ್ ಆಫ್ ಕ್ರೆಸಿಡಾ' ನಾಟಕದ ನಾಯಕಿಯ ಪಾತ್ರವಾಗಿದೆ.

ಡೆಸ್ಡಿಮೋನಾ 64 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿರುವ ಇದು ಶೆಕ್ಸ್‌ಪಿಯರನ ಒಥೆಲೋ ನಾಟಕದ ನಾಯಕಿಯ ಪಾತ್ರದ ಹೆಸರಾಗಿದೆ. ಇದು ಅನಿಯಮಿತ ಆಕಾರದಲ್ಲಿದ್ದು, ಬಿಯಾಂಕ ಮತ್ತು ಜೂಲಿಯಟ್ ನಡುವಿನ ಕಕ್ಷೆಯಲ್ಲಿ ಸುತ್ತುತ್ತಿದೆ.

ಜೂಲಿಯಟ್ 93 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದ್ದು ಶೇಕ್ಸ್‌ಪಿಯರ್‌ನ 'ರೋಮಿಯೋ ಮತ್ತು ಜೂಲಿಯಟ್' ನಾಟಕದ ನಾಯಕಿಯ ಪಾತ್ರದ ಹೆಸರಾಗಿದೆ.

ಪೋರ್ಷಿಯಾ 140 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದ್ದು, ಶೇಕ್ಸ್‌ಪಿರ್‌ನ 'ಮರ್ಚೆಂಟ್ ಆಫ್ ವೆನಿಸ್' ನಾಟಕದ ನಾಯಕಿಯ ಪಾತ್ರವಾಗಿದೆ. ಇದರ ಗುರುತ್ವಬಲವು ಸ್ವಲ್ಪ ಹೆಚ್ಚಾಗಿರುವುದರಿಂದ, ಹತ್ತಿರದ ಚಂದಿರರಿಗೆ ಪ್ರಭಾವ ಬೀರುತ್ತದೆ.

ರೊಸಾಲಿಂಡ್ ಅಂತರಿಕ ಚಂದಿರನನ್ನು 1986ರಲ್ಲಿ ವಾಯೇಜರ್–2ರಿಂದ ಕಂಡುಹಿಡಿಯಲಾಗಿದೆ. ಇದು 72 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದ್ದು, ಶೇಕ್ಸ್‌ಪಿಯರನ 'ಆಸ್ ಯು ಲೈಕ್ ಇಟ್' ನಾಟಕದ ಗಡಿಪಾರು ಮಾಡಿದ ಡ್ಯೂಕ್‌ನ ಮಗಳ ಹೆಸರಾಗಿದೆ. ಸ್ವಲ್ಪ ಕಪ್ಪು ಬಣ್ಣವಿದ್ದು ಕಡಿಮೆ ಬೆಳಕನ್ನು ಪ್ರತಿಫಲಿಸುತ್ತದೆ.

ಬೆಲಿಂಡಾ ಹೆಸರು ಅಲೆಕ್ಸಾಂಡರ್ ಪೋಪ್ ಅವರ ಪ್ರಸಿದ್ಧ ಕಾವ್ಯ 'ದಿ ರೇಪ್ ಆಫ್ ದ ಲಾಕ್'ನ ನಾಯಕಿ ಬೆಲಿಂಡಾ **ಎಂಬ** ಪಾತ್ರದಿಂದ ಬಂದಿದೆ. ಇದರ ಮೇಲ್ಮೈಯು ಮಂಜುಗಡ್ಡೆ ಮತ್ತು ಕಲ್ಲಿನ ಸಂಯೋಜನೆಯಿಂದ ಕೂಡಿದೆ.

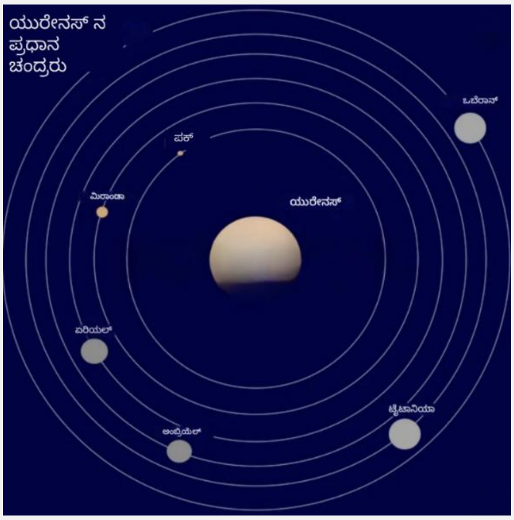
ಪಕ್ 162 ಕಿ.ಮೀ. ವ್ಯಾಸವಿರುವ ಅತಿ ಪ್ರಕಾಶಮಾನವಾದ ಚಂದಿರನಾಗಿದ್ದು, ಶೇಕ್ಸ್‌ಪಿಯರ್‌ನ 'ಎ ಮಿಡ್‌ಸಮ್ಮರ್ ನೈಟ್ಸ್ ಡ್ರೀಮ್'ನ ಹಾಸ್ಯ ಪಾತ್ರವಾಗಿದೆ. ಇದು ಮೇಲ್ಮೈನಲ್ಲಿ ಸಣ್ಣ ಕ್ರೇಟರ್‌ಗಳನ್ನು ಹೊಂದಿದ್ದು, 1885ರಲ್ಲಿ ವಾಯೇಜರ್–2ರಿಂದ ಕಂಡುಹಿಡಿಯಲಾಗಿದೆ.

ಪರ್ಡಿಟಾ 1999ರಲ್ಲಿ ಹಬಲ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕದಿಂದ ಕಂಡುಹಿಡಿಯಲಾಗಿದೆ. ಇದು ಶೇಕ್ಸ್‌ಪಿಯರ್‌ನ 'ವಿಂಟರ್ ಟೇಲ್'ನಿಂದ ಈ ಹೆಸರು ಬಂದಿದೆ. ಇದು ರೊಸಾಲಿಂಡಾ ಹತ್ತಿರ ಸುತ್ತುತ್ತಿದೆ. ವಾಯೇಜರ್–2 ನಲ್ಲಿ ತೆಗೆದ ಚಿತ್ರದಿಂದ ಮೊದಲು ಕಂಡುಬಂದಿದ್ದರೂ ನಂತರ ದೃಢೀಕರಿಸಲಾಯಿತು.

ಮಾಬ್ 24 ಕಿ.ಮೀ. ವ್ಯಾಸವಿರುವ ಇದು 2003ರಲ್ಲಿ ಹಬಲ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕದಿಂದ ಪತ್ತೆಮಾಡಲಾಗಿದೆ. ಇದು 'ರೋಮಿಯೋ ಮತ್ತು ಜೂಲಿಯಟ್' ನಾಟಕದಲ್ಲಿ ರಾಣಿ 'ಮಾಬ್'ನ ಹೆಸರಾಗಿದ್ದು, ಅತ್ಯಂತ ಸಣ್ಣ ಮತ್ತು ದುರ್ಬಲ ಬೆಳಕಿನ ಚಂದ್ರನಾಗಿದೆ.

ಕುಪಿಡ್ 18 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿ ಅತಿ ಸಣ್ಣಗಿದ್ದು, ನಿಧಾನ ಗತಿಯಲ್ಲಿ ಚಲಿಸುವ ಚಂದ್ರನಾಗಿದೆ. ಇದು ಶೇಕ್ಸ್‌ಪಿಯರನ 'ಟಿಮನ್ ಆಫ್ ಅಥೆನ್ಸ್' ನಾಟಕದ ಪಾತ್ರದ ಹೆಸರಾಗಿದೆ. ರೊಸಾಲಿಂಡ್ ಮತ್ತು ಪರ್ಡಿಟಾ ನಡುವೆ ಯುರೇನಸ್‌ಅನ್ನು ಸುತ್ತುತ್ತಿದೆ.

ಐದು ಪ್ರಧಾನ ಚಂದಿರರು(***Major moons***)ಗಳೆಂದರೆ ಮಿರಾಂಡಾ, ಏರಿಯಲ್, ಅಂಬ್ರಿಯಲ್, ಟೈಟಾನಿಯಾ, ಮತ್ತು ಒಬೆರಾನ್ (ಚಿತ್ರ 4). ಅವುಗಳ ವ್ಯಾಸವು ಮಿರಾಂಡಾ 472 ಕಿ.ಮೀ.ನಿಂದ ಟೈಟಾನಿಯಾ 1578 ಕಿ.ಮೀ.ವರೆಗೆ ಇವೆ. ಈ ಚಂದಿರರಲ್ಲಿ ಅಂಬ್ರಿಯಲ್ ಅತಿಯಾದ ಕಪ್ಪುಬಣ್ಣವಾದರೆ ಏರಿಯಲ್ ಪ್ರಕಾಶಿಸುತ್ತಿದೆ.



ಚಿತ್ರ 4 ಪ್ರಧಾನ ಚಂದಿರರು

ಮಿರಾಂಡಾ ಐದು ಪ್ರಧಾನ ಚಂದಿರರುಗಳಲ್ಲಿ ಯುರೇನಸ್‌ಗೆ ಹತ್ತಿರದ ಚಂದಿರ ಮತ್ತು ಅತ್ಯಂತ ಕಿರಿಯದಾಗಿದೆ. ಇದನ್ನು 1948ರಲ್ಲಿ ನೆದರ್‌ಲ್ಯಾಂಡ್ ಮೂಲದ ಅಮೆರಿಕದ ಖಗೋಳವಿಜ್ಞಾನಿ ಜೆರಾಲ್ಡ್ ಕೈಪರ್ ಕಂಡುಹಿಡಿದರು. ಶೇಕ್ಸ್‌ಪಿಯರ್‌ನ ಟೆಂಪೆಸ್ಟ್ ನಾಟಕದಲ್ಲಿನ ಪ್ರೊಸ್ಪೆರೋನ ದಯೆ ಮತ್ತು ನಿರ್ಮಲತೆಯ ಪ್ರತೀಕವಾದ ಮಗಳು ಮಿರಾಂಡಳ ಹೆಸರಾಗಿದೆ. ಇದರಲ್ಲಿ ಅನೇಕ ದೊಡ್ಡ ಕುಳಿಗಳಿದ್ದು, ಒಂದು ಕುಳಿಯು ಗ್ರ್ಯಾಂಡ್ ಕ್ಯಾನಿಯನ್‌ಗಿಂತ 12ಪಟ್ಟು ಆಳವಿದೆ. ಇದು 470 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದ್ದು, ಮೇಲ್ಮೈಯು ಚಿತ್ತಾರಗಳ ಜೋಡಣೆಗಳಂತಿದೆ.

ಏರಿಯಲ್ ಬೆಳಕು ಹೆಚ್ಚು ಪ್ರತಿಫಲಿಸುವುದರಿಂದ ಬಿಳಿಬಣ್ಣವನ್ನು ಹೊಂದಿದೆ. 1851ರಲ್ಲಿ ವಿಲಿಯಂ ಲಾಸ್ಸೆಲ್ ಎಂಬ ಖಗೋಳವಿಜ್ಞಾನಿ ಕಂಡುಹಿಡಿದರು. ಪ್ರಧಾನ ಚಂದಿರರಲ್ಲಿ ಚಿಕ್ಕದಾದ ಇದು 1160 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದೆ. ಕೆಲವು ಚಿಕ್ಕ–ದೊಡ್ಡ ಕುಳಿಗಳಿಂದ ಕೂಡಿದ್ದು ಅವು ಈಚಿನ ಘರ್ಷಣೆಗಳಿಂದ ಆದವುಗಳಂತೆ

ಇವೆ. ಮೇಲ್ಮೈಯಲ್ಲಿ ನದಿಗಳ ಹಾದಿಯಂತಿರುವ ವಿನ್ಯಾಸವಿದೆ. ಏರಿಯಲ್, ಅಲೆಕ್ಸಾಂಡರ್ ಪೋಪ್ ಅವರ ಪ್ರಸಿದ್ಧ 'ದಿ ರೇಪ್ ಆಫ್ ದ ಲಾಕ್' ಕಾವ್ಯ ಮತ್ತು ಶೇಕ್ಸ್‌ಪಿಯರ್‌ನ ಟೆಂಪೆಸ್ಟ್ ನಾಟಕ ಎರಡಲ್ಲೂ ಈ ಪಾತ್ರದ ಹೆಸರು ಬರುತ್ತದೆ. ಏರಿಯಲ್ ಎಂದರೆ ಬೆಳಕು, ಗಾಳಿ ಮತ್ತು ಶುದ್ಧತೆಯ ಪ್ರತೀಕವಾಗಿದೆ.

ಅಂಬ್ರಿಯಲ್‌ನ ವ್ಯಾಸ 1170 ಕಿ.ಮೀ. ಇದ್ದು ಸೂರ್ಯನ ಬೆಳಕನ್ನು ಕಡಿಮೆ ಪ್ರತಿಫಲಿಸುವುದರಿಂದ ಕತ್ತಲೆಯಿಂದ ಕೂಡಿದೆ. ಇದು ಅಲೆಕ್ಸಾಂಡರ್ ಪೋಪ್ ಅವರ 'ದಿ ರೇಪ್ ಆಫ್ ದ ಲಾಕ್' ಕಾವ್ಯದ ಪಾತ್ರದ ಹೆಸರಾಗಿದ್ದು ಕತ್ತಲೆ ದುಃಖ ಮತ್ತು ನೆರಳಿನ ಆತ್ಮವನ್ನು ಪ್ರತಿನಿಧಿಸುತ್ತದೆ. ಇದನ್ನೂ 1851ರಲ್ಲಿ ವಿಲಿಯಂ ಲಾಸ್ಸೆಲ್ ಕಂಡುಹಿಡಿದರು.

ಟೈಟಾನಿಯಾ ಯುರೇನಸ್‌ನ ಅತ್ಯಂತ ದೊಡ್ಡ ಚಂದಿರನಾಗಿದ್ದು, 1580 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದೆ. ಇದನ್ನು 1787ರಲ್ಲಿ ಸರ್ ವಿಲಿಯಂ ಹರ್ಷಿಲ್ ಕಂಡುಹಿಡಿದರು. ಮೇಲ್ಮೈಯಲ್ಲಿ ದೊಡ್ಡ ಕಣಿವೆಗಳಿದ್ದು, ಬಿರುಕುಗಳನ್ನೊಳಗೊಂಡಿವೆ. ಇದು ಶೇಕ್ಸ್‌ಪಿಯರ್‌ನ 'ಎ ಮಿಡ್ ಸಮ್ಮರ್ ನೈಟ್ಸ್ ಡ್ರೀಮ್' ನಾಟಕದ ರಾಣಿ ಓಬಿರಾನ್‌ನ ಪತ್ನಿಯ ಹೆಸರಾಗಿದೆ.

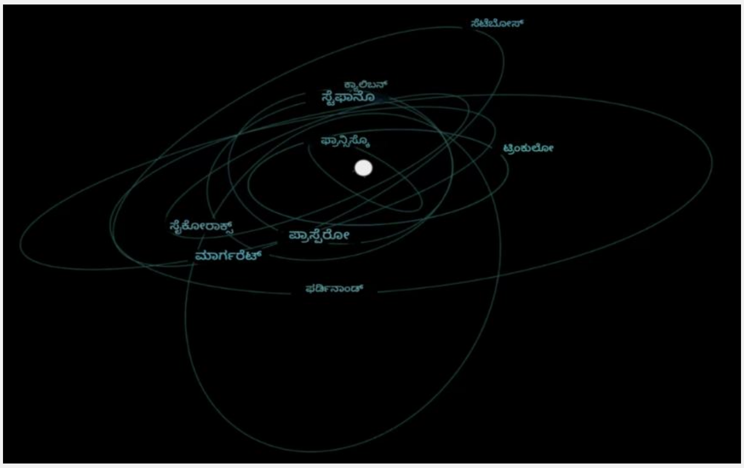
ಓಬೆರಾನ್ 1523 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದ್ದು, ಕುಳಿಗಳಿಂದ ತುಂಬಿದ ಮೇಲ್ಮೈಯನ್ನು ಹೊಂದಿದೆ. ಯುರೇನಸ್‌ನ ಎರಡನೇ ಅತಿ ದೊಡ್ಡ ಚಂದಿರನಾಗಿದ್ದು, 1787ರಲ್ಲಿ ಸರ್ ವಿಲಿಯಂ ಹರ್ಷಿಲ್ ಕಂಡುಹಿಡಿದರು. ಇದು ಶೇಕ್ಸ್‌ಪಿಯರ್‌ನ 'ಎ ಮಿಡ್ ಸಮ್ಮರ್ ನೈಟ್ಸ್ ಡ್ರೀಮ್' ನಾಟಕದ ರಾಜನ ಪಾತ್ರದ ಹೆಸರಾಗಿದೆ.

ಒಂಬತ್ತು ಅನಿಯಮಿತ ಬಾಹ್ಯ ಚಂದಿರರು: ಪ್ರಧಾನ ಚಂದಿರರ ನಂತರ ಈ ಅನಿಯಮಿತ ಬಾಹ್ಯ ಚಂದಿರರಾದ ಫ್ರಾನ್ಸಿಸ್ಕೋ, ಸ್ಟೆಫಾನೊ, ಕ್ಯಾಲಿಬಾನ್, ಸೈಕೊರಾಕ್ಸ್, ಪ್ರೊಸ್ಪೆರೊ, ಮಾರ್ಗರೇಟ್, ಫರ್ಡಿನಾಂಡ್, ಟ್ರಿನ್‌ಕ್ಯುಲೋ ಮತ್ತು ಸೆಟಿಬಾಸ್ ಯುರೇನಸ್‌ನನ್ನು ಅಂಡಾಕಾರದಲ್ಲಿ ಮತ್ತು ಓರೆಯಾಗಿ ಬಹು ದೂರದಲ್ಲಿ ಸುತ್ತುತ್ತಿವೆ (ಚಿತ್ರ 5). ಈ ಬಾಹ್ಯ ಅನಿಯಮಿತ ಚಂದಿರರು ಕೂಪಿಯರ್ ಪಟ್ಟೆಯಲ್ಲಿನ ಕಾಯಗಳನ್ನು ಯುರೇನಸ್ ತನ್ನ ಗುರುತ್ವಾಕರ್ಷಣೆಯಿಂದ ಸೆರೆಹಿಡಿದವುಗಳೆಂದು ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಹೇಳುತ್ತಾರೆ. ಸೆಟಿಬೋಸ್, ಸ್ಟೆಪಾನೊ, ಪ್ರಾಸ್ಪೆರೊ ಮತ್ತು ಟ್ರಿನ್‌ಕ್ಯುಲೊ ಚಂದಿರರು 1990ರಿಂದ 2001ರ ವರೆಗೆ ಹಬಲ್ ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕ ಮೌನ ಕಿಯಾ ಮತ್ತು ಚಿಲಿ ವೀಕ್ಷಣಾಲಯಗಳಲ್ಲಿ ಕಂಡುಹಿಡಿಯಲಾಗಿದೆ.

ಫ್ರಾನ್ಸಿಸ್ಕೋ 2001ರಲ್ಲಿ ಕಂಡುಹಿಡಿಯಲಾಗಿದ್ದು ಕೇವಲ 22 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದೆ. ಇದು ಅನಿಯಮಿತ 'ಃಬಿಟಜ ಣಜಚಂದಿರನಾಗಿದ್ದು ಹಿಮ್ಮುಖನಾಗಿ ಯುರೇನಸ್‌ಅನ್ನು ಸುತ್ತುತ್ತಿದೆ. ಇದರ ಹೆಸರು ಶೇಕ್ಸ್‌ಪಿಯರನ ಟೆಂಪೆಸ್ಟ್ ನಾಟಕದಲ್ಲಿ ನೌಕಾ ಪಡೆಯ ಸದಸ್ಯನದು.

ಸ್ಟೆಪಾನೊ ಚಂದಿರನು 1999ರಲ್ಲಿ ಹವಾಯ್‌ನ ಮೌನಕಿಯಾ ವೀಕ್ಷಣಾಲಯದಲ್ಲಿ ಕಂಡುಹಿಡಿಯಲಾಯಿತು. ಇದು ಯುರೇನಸ್‌ನ ಚಿಕ್ಕ ಚಂದಿರನಾಗಿದ್ದು ಹಿಮ್ಮುಖನಾಗಿ ಚಲಿಸುತ್ತಿದೆ. ಇದರ ಹೆಸರು ಟೆಂಪೆಸ್ಟ್ ನಾಟಕದ ರಾಜ ಅಲೊನ್ಸೊನ ಸೇವಕನ ಹೆಸರಾಗಿದೆ.

ಕ್ಯಾಲಿಬಾನ್ 1997ರಲ್ಲಿ ಖಗೋಳವಿಜ್ಞಾನಿ ಬ್ರೆಟ್ ಜೆ ಗ್ಲಾಡ್‌ಮನ್ ಮತ್ತು ಸಂಗಡಿಗರಿಂದ ಕಂಡುಹಿಡಿಯಲಾಗಿದೆ. ಹಿಮ್ಮುಖನಾಗಿ ಚಲಿಸುತ್ತಿದ್ದು 72 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದೆ. ಇದು ಟೆಂಪೆಸ್ಟ್ ನಾಟಕದಲ್ಲಿ ದೈತ್ಯ ಸ್ವಭಾವದ ಪಾತ್ರದ ಹೆಸರಾಗಿದೆ.



ಚಿತ್ರ 5 ಅನಿಯಮಿತ ಬಾಹ್ಯ ಚಂದಿರರು

ಸೈಕೊರಾಕ್ಸ್ ಚಂದಿರನನ್ನು 1997ರಲ್ಲಿ ಪಾಲ್ಮರ್ ವೀಕ್ಷಣಾಲಯದ 200 ಅಂಗುಲದ ಹಾಲೆ ದೂರದರ್ಶಕದಿಂದ ಕಂಡುಹಿಡಿಯಲಾಗಿದೆ. ಸುಮಾರು 150 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿರುವ ಯುರೇನಸ್‌ನ ಅನಿಯಮಿತ ಚಂದಿರರಲ್ಲಿ ಅತಿ ದೊಡ್ಡದಾಗಿದ್ದು ಕತ್ತಲೆಯಿಂದ ಕೂಡಿದೆ. ಯುರೇನಸ್‌ನಿಂದ 12 ದಶಲಕ್ಷ ಕಿ.ಮೀ. ದೂರದಲ್ಲಿ ಹಿಮ್ಮುಖನಾಗಿ ಸುತ್ತುತ್ತಿದೆ. ಇದರ ಕಕ್ಷೆಯು ಸೆಟಿಬೋಸ್ ಮತ್ತು ಪ್ರಾಸ್ಪೆರೊ ಚಂದಿರರಂತೆಯೇ ಇರುವುದರಿಂದ, ಇವೆಲ್ಲಾ ಒಂದೇ ಮೂಲದಿಂದ ರೂಪಿತವಾಗಿರಬಹುದೆಂದು ಊಹಿಸಲಾಗಿದೆ. ಇದು ಕೆಂಪುಬಣ್ಣವನ್ನು ಹೊಂದಿದ್ದು ಉಳಿದೆರಡು ಬೂದುಬಣ್ಣದವಾಗಿವೆ. ಸೈಕೊರಾಕ್ಸ್ ಟೆಂಪೆಸ್ಟ್ ನಾಟಕದ ಮಾಟಗಾತಿಯ ಹೆಸರಾಗಿದೆ.

ಪ್ರೊಸ್ಪೆರೋ 1999ರಲ್ಲಿ ಪತ್ತೆ ಮಾಡಲಾಗಿದ್ದು, 25 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದೆ. ಇದು ಬಹಳ ದೂರ ಇದ್ದು ಧೂಳು ಮತ್ತು ಕಲ್ಲಿನಿಂದ ಕೂಡಿದೆ. ಹಿಮ್ಮುಖನಾಗಿ ಚಲಿಸುತ್ತಿರುವ ಪ್ರೊಸ್ಪೆರೋ, ಟೆಂಪೆಸ್ಟ್ ನಾಟಕದ ಜಾದೂಗಾರನ ಪಾತ್ರದ ಹೆಸರಾಗಿದೆ.

ಮಾರ್ಗರೇಟ್ 2003ರಲ್ಲಿ ಪತ್ತೆಯಾಗಿದ್ದು, 20 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿದೆ. ಅನಿಯಮಿತ ಚಂದಿರುಗಳಲ್ಲಿ ಇದೊಂದು ಮಾತ್ರ ಪ್ರದಕ್ಷಿಣಾಕಾರವಾಗಿ ಚಲಿಸುತ್ತಿದೆ. ಇದು ಶೇಕ್ಸ್‌ಪಿಯರನ 'ಮಚ್ ಅಡು ಅಬೌಟ್ ನಥಿಂಗ್' ನಾಟಕದ ಪಾತ್ರದ ಹೆಸರಾಗಿದೆ.

ಫರ್ಡಿನಾಂಡ್ 2001ರಲ್ಲಿ ಪತ್ತೆಯಾಗಿದ್ದು, ಸುಮಾರು 20ರಿಂದ 25 ಕಿ.ಮೀ. ವ್ಯಾಸವನ್ನು ಹೊಂದಿ, ಬಹಳ ದೂರದಲ್ಲಿದ್ದು ಕತ್ತಲೆಯಲ್ಲಿ ಚಲಿಸುತ್ತಿದೆ. ಇದು ಟೆಂಪೆಸ್ಟ್ ನಾಟಕದ ರಾಜಕುಮಾರನ ಹೆಸರು.

ಟ್ರಿನ್‌ಕ್ಯುಲೋ ಸುಮಾರು 18 ಕಿ.ಮೀ. ವ್ಯಾಸವಿರುವ ಇದು 2001ರಲ್ಲಿ ಪತ್ತೆಯಾಗಿದೆ. ಕಪ್ಪು ಬಣ್ಣದಿಂದ ಕೂಡಿದ ಇದು ಹಿಮ್ಮುಖನಾಗಿ ಚಲಿಸುತ್ತಿದೆ. ಇದು ಟೆಂಪೆಸ್ಟ್ ನಾಟಕದ ವಿದೂಷಕನ ಪಾತ್ರವಾಗಿದೆ.

ಸೆಟಿಬೋಸ್: ಇದನ್ನು 1999ರಲ್ಲಿ ಹವಾಯ್‌ನ ಮೌನಕಿಯಾ ವೀಕ್ಷಣಾಲಯದಲ್ಲಿ ಕಂಡುಹಿಡಿಯಲಾಗಿದೆ. 48 ಕಿ.ಮೀ. ವ್ಯಾಸವುಳ್ಳ ಚಿಕ್ಕ ಚಂದಿರನಾಗಿದ್ದು, ಯುರೇನಸ್‌ಗೆ ಹಿಮ್ಮುಖನಾಗಿ ಚಲಿಸುತ್ತಿದೆ. ಸೆಟಿಬೋಸ್ ಯುರೆನಸ್‌ಗೆ ಅತಿ ದೂರದಲ್ಲಿ 17 ದಶಲಕ್ಷ ಕಿ.ಮೀ. ದೂರದಲ್ಲಿ ಸುತ್ತುತ್ತಿದೆ. ಇದರ ಕಕ್ಷೆಯ ಗುಣಲಕ್ಷಣಗಳು ಪ್ರಾಸ್ಪರೋ ಮತ್ತು ಸೈಕೊರಾಕ್ಸ್ ಚಂದಿರನ್ನು ಹೋಲುತ್ತದೆಯಾದ್ದರಿಂದ ಒಂದೇ ಮೂಲದಿಂದ ರೂಪಿತವಾಗಿದೆ ಎಂದು ಖಗೋಳವಿಜ್ಞಾನಿಗಳು ಹೇಳುತ್ತಾರೆ. ಇದರ ಹೆಸರು ಟೆಂಪೆಸ್ಟ್ ನಾಟಕದಲ್ಲಿ ಬರುವ ದೇವತೆಯದು.

ಒಟ್ಟಾರೆ ಯುರೇನಸ್‌ನ ಚಂದಿರರು ನಮಗೆ ಶೇಕ್ಸ್‌ಪಿಯರನ ನಾಟಕಗಳನ್ನು ನೆನಪಿಸುತ್ತದೆಯಲ್ಲದೆ ಅವುಗಳನ್ನು ಪನಃ ಓದುವಂತೆಯೂ ಮಾಡುವುದರಲ್ಲಿ ಯಾವ ಸಂದೇಹವೇ ಇಲ್ಲ.

ಇದುವರೆಗೆ ಯುರೇನಸ್‌ನ ಸಂಶೋಧನೆಯು ಬಾಹ್ಯಾಕಾಶ ದೂರದರ್ಶಕಗಳು ಮತ್ತು ವಾಯೇಜರ್–2 ಬಾಹ್ಯಾಕಾಶ ನೌಕೆಯ ಮೂಲಕ ಮಾತ್ರ ಅಧ್ಯಯನ ಮಾಡಿದ್ದಾರೆ. 1977ರಲ್ಲಿ ಮಾನವ ನಿರ್ಮಿತ ಬಾಹ್ಯಾಕಾಶ ಉಪಗ್ರಹವಾದ ವಾಯೇಜರ್–2ಅನ್ನು ನಾಸಾ ಸಂಸ್ಥೆಯಿಂದ ಉಡಾವಣೆ ಮಾಡಲಾಯಿತು. ಅದು 1986ರಲ್ಲಿ ಯುರೇನಸ್ ಸಮೀಪದಲ್ಲಿ ಹೋಗಿ, ಯುರೇನಸ್‌ನ ವಾತಾವರಣದ ಅನೇಕ ಮಾಹಿತಿಯನ್ನು ಭೂಮಿಗೆ ರವಾನಿಸಿದೆ ಮತ್ತು ಅದರ 5 ದೊಡ್ಡ ಚಂದಿರರ ಚಿತ್ರಣಗಳನ್ನು ಸೆರೆಹಿಡಿದಿದೆ. ಅವುಗಳಲ್ಲಿ ಅನೇಕ ಕುಳಿಗಳು ಮತ್ತು ಕಣಿವೆಗಳಿವೆ ಎಂಬ ಮಾಹಿತಿ ತಿಳಿದುಬಂದಿದೆ. ಹಬಲ್ ದೂರದರ್ಶಕವು ಹದಿಮೂರು ಉಂಗುರಗಳ ಚಿತ್ರಣವನ್ನು ಸೆರೆಹಿಡಿದಿದೆ.

ಇತ್ತೀಚೆಗೆ 10 ಕಿ.ಮೀ .ವ್ಯಾಸವುಳ್ಳ ಖ/2025ಗ1 ಜಒಛ ಎಂಬ ಹೊಸದೊಂದು ಚಂದಿರನನ್ನು ಜೇಮ್ಸ್ ವೆಬ್ ದೂರದರ್ಶಕವು ಪತ್ತೆಮಾಡಿದೆ. ಹೀಗಾಗಿ ಚಂದಿರರ ಸಂಖ್ಯೆ 28ಕ್ಕೆ ಬದಲಾಗಿ 29 ಆಗಿದೆ.

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ಅರುಣ ಭಾಗ್ಯ

ಸೂರ್ಯನ ಸಾರಥಿ ನೀ ಶಾಂತ ಸ್ವಭಾವ
ನೀ ಯುರೇನಸ್ ಗ್ರೀಕರ ಅಂಬರ ದೇವ11
ದರ್ಶಕದ ಮೊದಲ ಗ್ರಹವಾಗಿರುವೆಯತ್ತ
ಬದಿಯಲಿ ಉರುಳುವೆ ಸೂರ್ಯನ ಸುತ್ತ11
ನೀಲಿ ಬೆಳಕಿನ ಹೊಳಪಿನಲಿ
ವಜ್ರದಲರಳಿಹೆ ಬಹು ತಾಪದಲಿ11
ಧ್ರುವಗಳಲಿ ಬೆಳಕು ಕತ್ತಲೆ ದೀರ್ಘ
ನಲವತ್ತೆರಡರ ಸಮನಾದ ವರ್ಷ11
ನಿನಗಿಹರು ಚಂದಿರರವರು ಇಪ್ಪತ್ತೆಂಟು
ಅವರಿಗಿಹುದು ಶೇಕ್ಸ್‌ಪಿಯರ್ ನಾಟಕ ನಂಟು11
ಮಿರಾಂಡ ಐವರು ಹಿರಿಯರಿಹರು
ಜೂಲಿಯಟ್ ಮಾರ್ಗರೇಟ್ ಚಿಕ್ಕವರವರು11
ತೊಡಿಸಿಹರು ಉಂಗುರಗಳ ಹದಿಮೂರು
ಅದರ ಹೊದಿಕೆಯಲಿ ಚಿಕ್ಕ ಚಂದಿರರ ಹರಿವು11
ವಾಯುಮಂಡಲವು ನಿನಗೆ ತಂಪಿನ ನಾಟ್ಯ
ಧ್ರುವಗಳಲಿ ವಿದ್ಯುತ್ ಜ್ವಲಂತ ಭಾಗ್ಯ11

– ಡಾ. ಶಾರದಾ ನಾಗಭೂಷಣ

BIOPHOTONS - AN INTRICATE RELATION BETWEEN LIFE AND LIGHT

Alexander Gurwitsch

WHAT ARE BIOPHOTONS (UPE)?

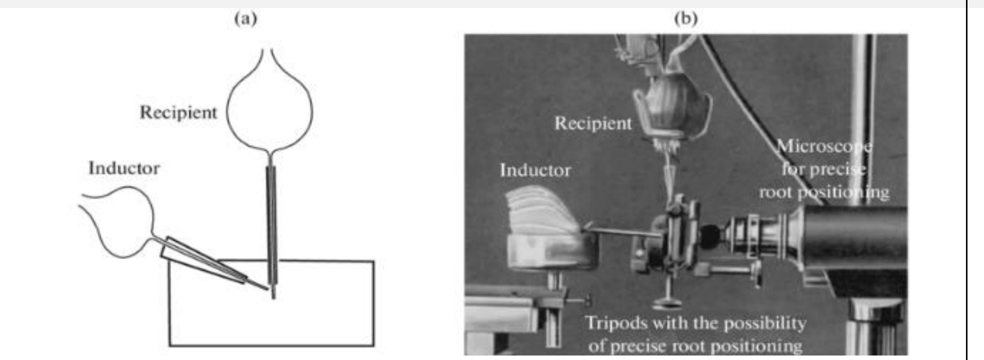
Biophotons are spontaneous Ultra weak emissions of photons (UPE)in the low visible and ultraviolet energy range (200 to 1000nm), emitted by all biological systems, including humans, even in the absence of external light sources. Unlike the bioluminescence of fireflies, glow worms or jellyfish (in these organisms Luciferine reacts with oxygen catalysed by enzyme Luciferase to produce light), the biophoton emission is faint- often just a few photons per sq cm/sec (1 to 1000)- and detectable only with highly sensitive instruments in total darkness. First proposed by Alexander Gurwitsch as "mitogenetic radiation", nearly a century ago, biophotons were initially dismissed as artefact due to the limitations of contemporary detection technology. It has been known for more than a century that all living cells do emit these ultra weak light photons and this emission stops the moment the living organism is dead.

WHY THESE ULTRA WEAK PHOTON EMISSIONS (UPE) FROM LIVING ORGANISMS ARE NOT DUE TO DELAYED LUMINESCENCE (DL)?

In DL, materials biological or otherwise, exhibit a long-lasting luminescence even after the illuminating source has been removed or shut off. The intensity of DL, like UPE, is of orders of magnitude below typical fluorescence or phosphorescence. There is a distinction in the source that facilitates these two emissions; in UPE the emission of photons is spontaneous by metabolic emissions whereas DL occurs following exposure to light source.

FIRST OBSERVATION:

In 1923 Alexander Gurwitsch, a Russian scientist, explored the possibility of non-chemical and non-contact method of cell-to-cell communication in a series of experiments:



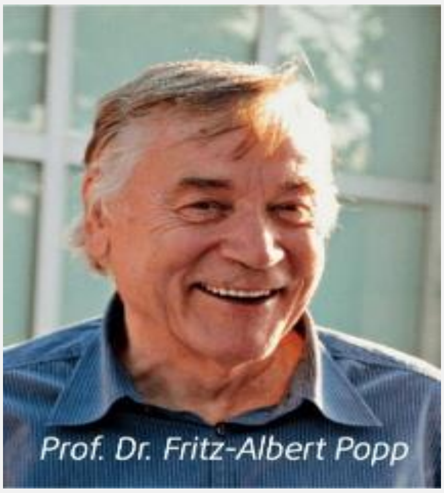
Alexander Gurwitsch onion experiment (Resource: ResearchGate)

In one such experiment he positioned the tip of an onion root (called inducer) perpendicular to another onion root (called receiver) close to its tip. The rate of cell division as assessed under a microscope in the second root (receiver) exposed to first root was found to be perceptibly greater than on the other unexposed side. This effect vanished on insertion of a glass plate between the two roots but showed up again when a quartz plate replaced glass plate. He hypothesised that certain radiations emitted from the tip of the first onion root caused the enhanced mitosis or cell division in the nearby second onion root(receiver). Since glass absorbs UV radiation, while quartz is transparent to it, he suggested that the radiation emanating from onion root tip probably contained UV component that influences the mitotic activity of nearby living organisms.

In another case Gurwitch found an increase in the turbidity of a growing yeast culture as cells multiplied, when observed under a microscope. The turbidity was measured by counting the number of cells in a block of yeast culture embedded in agar gel. Such UV radiation was also detected by the onset of growth in a bacterial culture. He thus termed these radiations emitted by an inducer cell causing cell division in receiver cell as "mitogenetic rays" or simply "mitogenic radiation" and proposed that mitogenic rays were a fundamental part of cellular communication and cellular division(mitosis).

This was a first report of "radiations" emitted by cells in living organisms. A compelling hypothesis thus emerged; a living organism has the capacity to emit photons that trigger cell division. He also found emission of secondary mitogenic radiations when a tissue is bombarded by primary mitogenic radiations.

Throughout 1930s, various scientists tried to replicate Gurwitsch's findings but only with mixed results. Alexander Gurwitsch was awarded Lenin prize for his works on mitogenetic radiations in 1941, for it had apparently lead to a simple and cheap way for treating cancer. In 1940s and 1950s, the scientific community largely dismissed mitogenic rays as artefact in the absence of technology for detection of this very low intensity photons. Langmuir, Nobel laureate in chemistry dismissed the concept of mitogenetic radiation as "pathological science" in 1953. However, Anna Gurwitsch, daughter of Alexander Gurwitsch using photon counter multiplier, an advanced technique for detection, confirmed the emission of these radiations in 1962.With the improved methods of detecting weak radiation and concepts of quantum optics, Colli and Facchini were also able to make the first measurements of these UPE emissions coming from the living organisms.

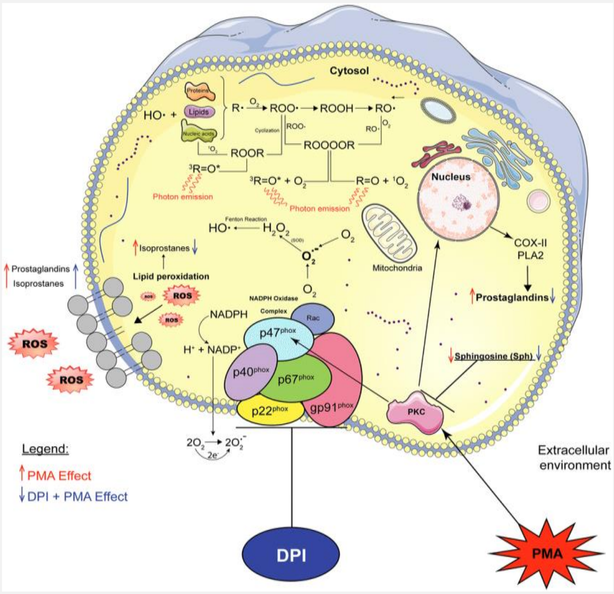


This work was taken up again 30 years later in 1980 by a German bio physicist **Fritz-Albert Popp and coworkers**, who started extensive work to understand more in detail the origin and meaning of such ultra-weak emissions. His ground breaking research revealed that the ultra-weak emissions of biological systems, whether of plant or animal origin, exhibited remarkable coherence across the entire detection range, spanning from UV to infra red portion of the electromagnetic spectrum. He demonstrated that not just individual organisms but also their communities, such as daphnia (an aquatic organism grows 0.5 to 1cm long, has transparent body cover, fodder for fish) in a small aquarium, seeds placed in a vessel, yeast cultures or animal cell suspensions, all behaved as coherent emitters of this radiation. By attracting quantum mechanical physical theory as well as modern theories of cavity quantum electrodynamics and of coherent electromagnetic fields and taking into consideration specific properties of biological electromagnetic radiations, Popp suggested a new term " bio photon emission" for this light emission from biological systems.

ORIGIN OF BIOPHOTONS

Two hypotheses have been proposed to explain the origin of these UPE or biophotons. In the first hypothesis it is tacitly assumed that biophoton emission is associated with oxidative metabolic reactions in cells, particularly those associated with oxidative metabolic reactions, involving formation of "reactive oxygen species (ROS)" during the process. As these biomolecules become oxidised, some enter excited electronic states. When the excited state molecules return to the ground state, they release energy in the form of photons. (a process similar to chemiluminescence but far weaker in intensity). These emissions are typically in the UV to visible range (200-800nm) and occur in all living cells, from bacteria to human (in human tissues, in the range 420-570nm). These molecules formed in excited states have a number of variants. Among these are the triplet excited carbonyls emitting mostly in the invisible part of the spectrum (350-550 nm), di molar doublet excited oxygen emitting around 634nm and 703nm, and mono molar singlet excited oxygen emitting in the infrared region. These molecules (ROS) are generated either during the normal functioning of the cell or initiated by various biotic and abiotic stressors (environmental factors that can disturb the normal physiology of living organisms often leading to oxidative stress - a condition where the production of reactive oxygen species exceeds the organism's anti oxide defences) and oxidative factors. What distinguishes biophotons from other forms of bioluminescence (fluorescence, phosphorescence) is its 'spontaneous' emission.

Alternatively, the second hypothesis initially suggested by K.A.Popp and later by others, attributes the emission to a coherent electromagnetic field generated both within and between the cells, presumably arising from biochemical reactions involving oxygen atoms. He proposed "DNA and Quantum emission theory" for origin of biophotons, suggesting that DNA is the primary source of coherent biophoton emission. Recent studies also have shown DNA to be significant source of these biophotons, validating Popp's hypothesis. (Ultra weak photon emission from DNA, nature, November 21,2024).



Other theories suggesting emission of biophotons as due to "quantum biological effects " and " environmental interaction effects" are in exploratory phase and need more experimental validation.

DETECTION

Biophotons require highly sensitive, low-noise instruments due to the extreme low intensity of these emissions. Below are the primary detection techniques and tools used in biophotons research and diagnostics.

Photomultiplier Tubes- Vacuum tube devices that detect photons and convert them into electrical signals. They are very sensitive, possess faster response time and can detect single photons.

Charge coupled Devices (CCD)-Semiconductor sensors used with cameras to detect light with high sensitivities. They are good for continuous monitoring and 2-D imaging.

EMCCD (Electron-multiplying CCD) - They are more sensitive and better suited for ultra-weak light. They can image entire tissue or cell cultures.

CMOS Sensors- Modern, energy efficient image sensors. They have faster read out times than CCD and are portable.

Photon counting systems- Used with PMTs to count individual photon events and have high temporal resolution.

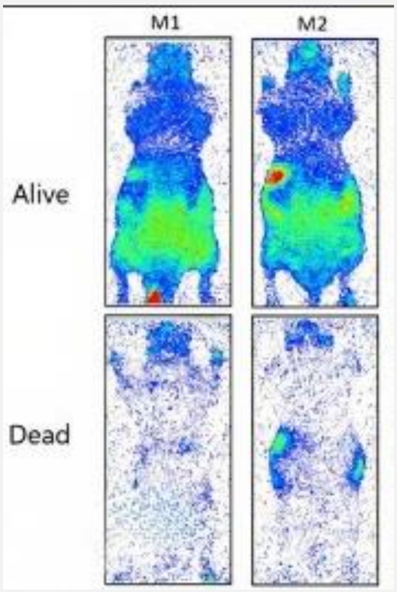
Spectral analysis tools- These are spectrometers or monochromators coupled with PMT or CCD. Helpful in studying fingerprints of diseased versus healthy tissues.

These devices are aided by completely sealed Dark chambers to eliminate external light contamination, Cryogenic cooling systems to reduce background noise and low-noise electronics to reduce signal artefacts. The subjects are placed in a completely dark chamber either for imaging or counting photons. These tools are now being explored in live cell imaging, photodynamic therapy and bio imaging.

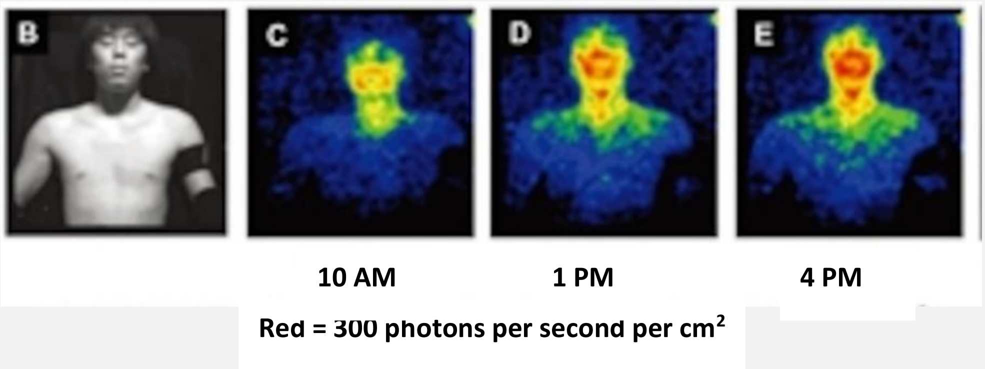
RESULTS OF SOME STUDIES WITH BIOPHOTONS

- The intensity of this light (UPE)is about $(1/1000)^{th}$ minimum intensity for our eye limit and thus being very low, is invisible to naked eye

- The wave length of the biophotons measures in the range 200-1000 nm.
- On an average the number of biophotons emitted lies in the range 1 to 1000 photons/sec/sq.cm of the surface (a light bulb emits around a billion photons per sec).
- Biophoton emissions are spontaneous and regulated.
- Biophotons are not of thermal radiation because a simple calculation using Planck's distribution law tells us that the intensity of the biophoton emission (10^{-12} W/sq.m) is several orders of magnitude smaller than that of thermal radiation (500 W/sq.m).
- The intensity distribution over wave length does not look like a bell-shaped curve, as met with thermal body spectrum, but shows a continuous curve superposed by irregular peaks.



- The emission of biophotons ends when the organism dies. This excludes the possibility that it is the radiation produced by decay of some radioactive traces present in the organism or by the passage of cosmic rays.
- Biophoton emission exhibits diurnal rhythm. It is closely linked to circadian rhythms, which are regulated by the body's internal clock and day-night cycles. In humans and animals, the emission levels are low in morning, increasing as day progresses, peaking during evening and decrease during night and reaching lowest in morning, in tune with metabolic activity and hormone levels that fluctuate throughout the day affecting the emission. Brain cells, liver and skin all show higher photon emission during active metabolic phases.



- Seasonal variation of spontaneous biophoton emission intensity, as measured, revealed as high as 4-fold changes over a year-long measurements, with the lowest intensity in the autumn and highest intensity appearing 6 months from autumn and decreasing thereafter. Bio photon emission tends to increase in summer and decrease in winter in both plants and animals probably due to changes in sunlight exposure and temperature which in turn affect metabolic rate and hormone levels. In plants bio photon emission shows strong seasonal cycles aligned with photosynthesis rates and chlorophyll activity.
- Biophoton emission rate may indicate health hazards in the body. Cancerous cells show unusually high rate of biophoton emission marked by sharp peaks in blue-green region of the biophoton spectrum. A study in Italy shows a mammalian tumour cell on an average emits around 1400 photons/sec compared to 10/sec from the healthy cell.

  - UPE (biophotons) measurement may provide a valuable tool for monitoring injury and wound healing in animals. (Following injury to the back of a mouse, the emission intensity gradually increasing and peaking between 3-5 days post injury. From 6d onward the emission intensity began to decline, ultimately returning to normal levels, coinciding with complete healing of the wound.

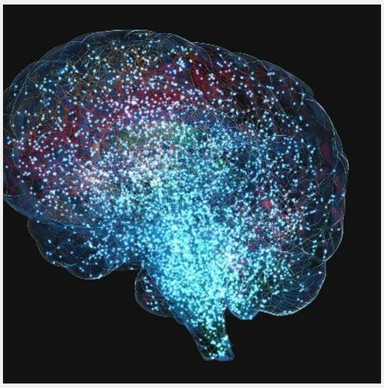
- UPE emissions from humanely euthanised mice ceased immediately.
- UPE emission rate varies both in intensity and spectral distribution, across different regions of the human body. It is the highest around forehead, high around cheeks, high to moderate from palms, lower than palms from back of hands and lowest from legs and feet. The emission rate in chest, though is higher, it measures less because of thick covering of the skin.

- The intensity of UPE emitted from the human body is found to be influenced by some physiological factors such as age, gender, biological rhythms and conscious activities.
- Biophoton emission can exhibit right-left asymmetry in human and other living organisms meaning the rate of emission from left part of the body may differ from the emission from right part. The emissions from the right side of face/cheeks or hands or forehead being slightly more than from left. This asymmetry is subtle but measurable. It is due to underlying physiological, neurological or pathological differences between the two sides of the body. Some studies have suggested the asymmetry in biophoton emission may be caused by an injury, local inflammation or infection on one side. Stroke, neuropathy or tumours may also cause asymmetric emission and help localisation of the disease.

Emission from Hand

BIOPHOTON EMISSION FROM HUMAN BRAIN:

The rate of emission from brain changed when participants switched between different cognitive tasks like -closing and opening eyes. This technique for imaging UPE emissions from brain is termed "Photoencephelography".

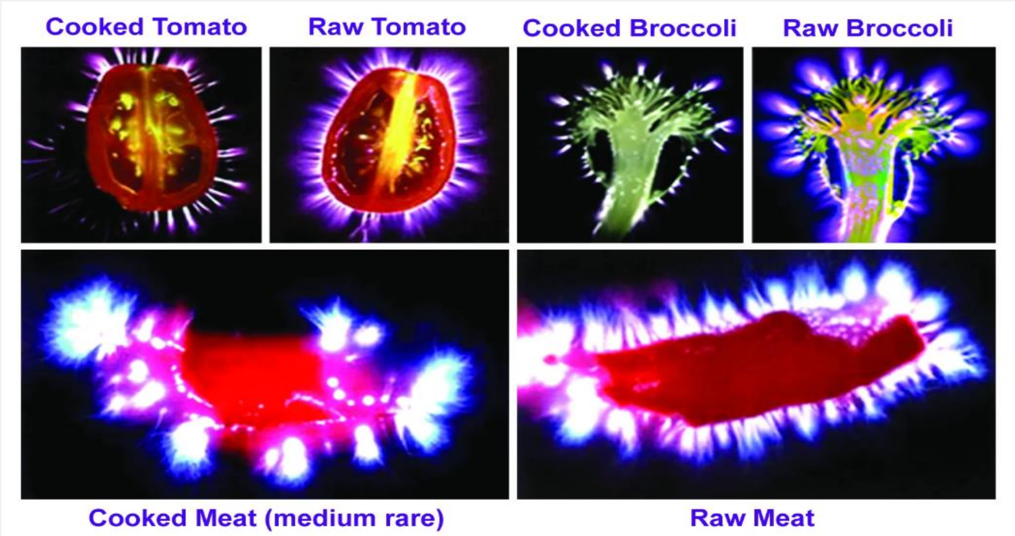


Biophotons exhibit coherent properties like temporal coherence, spectral coherence, spatial coherence which could be related to quantum processes in biological systems and might play a role in information processing and storage within living organisms.

Studies have shown that meditation can alter biophoton emission patterns potentially reflecting changes in brain activity or consciousness. It is reported that the UPE intensity from volunteers who practised transcendental meditation was lower than that of volunteers who neither practised such meditation / relaxation techniques.

Biophoton emission rate is higher in subjects emotionally stimulated to feel anger.

Biophotons produced in the brain may be indicative of optical channel communications in the brain.

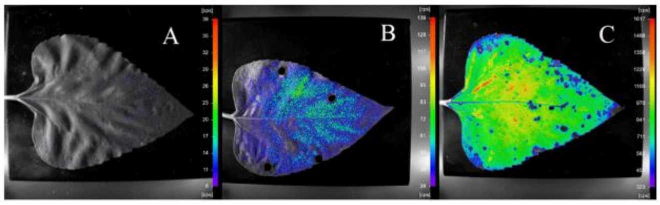


Emission of Biophtos in Vegetables

BIOPHOTON EMISSION IN PLANTS

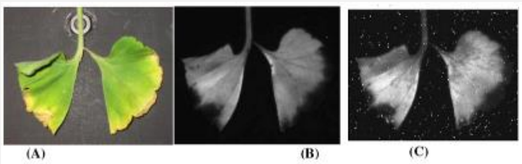
Biophoton emission in plants is a complex phenomenon influenced by environmental factors and soil composition. Rate of emission is higher from leaves followed by flowers, fruits, stem and roots. Studies have reported a sudden increase in rate of emission from leaf when it is cut. In the case of plants, Biophoton emission rate increases whenever plants are under stress- change in environment like drought, affected by pathogens, suffer insect infestations, undergo physical damage or get wounded.

Modelling biophoton emission kinetics based on the initial intensity value in *Helianthus annuus* plants exposed to different types of stress



The emission of UPE can serve as sensitive indicator of cellular metabolism, oxidative stress and physiological well-being.

In agriculture, monitoring biophoton emissions could provide a valuable, real-time indication of plant health being able to quickly identifying stress factors like drought or nutrient deficiencies. Such rapid detection would allow timely intervention, significantly improving crop management and yield outcomes..



Cut geranium leaf on black stage platform.

(A) White light image.

(B) Chlorophyll fluorescence image. 1-minute exposure in total darkness.

(C) Two-hour biophoton image after five hours in total darkness, Bright

In plants an increase in temperature and injuries both caused an increase in rate of biophoton emission. The chemical treatments modified the biphotonic emission rate particularly application of anaesthetics to injuries.

BIOPHOTONIC FIELD AROUND LIVING SYSTEM

Every organ of our body emits bio photon radiations. The emitted radiation generates a weak electromagnetic field around us characterised by an electromagnetic spectrum. The features of the spectrum may indicate the state of mind like stressed, relaxed or agitated and also if the subject is healthy or diseased. Electric fields across a cell membrane are of the order of 100000v/cm. Can these faint flashes of light emitted by the cells tell us what they are feeling? If so, is this the way our body expresses its feelings or talks! Kobayashi in Japan is trying construct a biophoton image of human body similar to X-ray or NMR

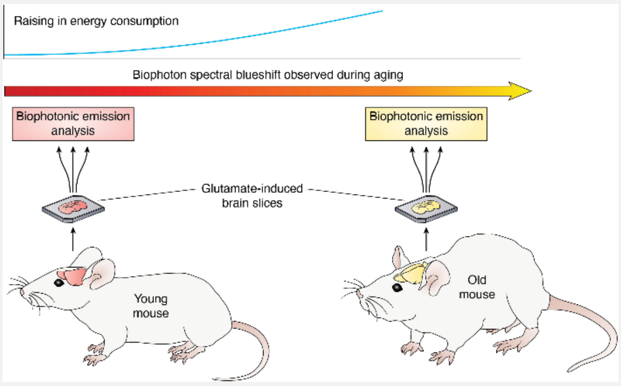
or pet scan image to diagnose the disease in the body. Thus, UPE imaging provides the possibility of non-invasive label-free imaging of vitality of animals and responses of plants to stress

ROLE OF CONSCIOUSNESS

The potential link between biophotons and consciousness is a subject of fascinating, though highly theoretical, research. One key hypothesis suggests these photons do not merely represent metabolic waste but form a crucial system of intercellular communication. Some theories propose that the brain's vast network of neurons uses these light signals to transmit information far faster than traditional electrochemical synapses. Researchers speculate that a highly coherent, organized biophoton field could correlate with the integrated, unified nature of consciousness. This concept aligns with quantum theories of the brain, suggesting consciousness is an emergent property of quantum phenomena. Studies have shown that brain biophoton emission intensity correlates with neural activity and the brain's energy metabolism. Furthermore, changes in biophoton coherence have been linked to different psychological or cognitive states. Ultimately, the idea is that biophotons may function as a holistic, non-local signaling system, forming the underlying information field from which consciousness emerges. This area remains speculative, pushing the boundaries between physics, biology, and the 'hard problem' of consciousness.

BLUESHIFT AND AGEING

Several studies indicate that the activity and transmission of biophotons in neural circuits may play a vital role in neural information processing and communication. The ageing processes of higher organisms are often accompanied by a decline in brain functions. The mechanism underlying these processes is not clear. The glutamate induced biophotonic emissions in mouse brain cells at different ages1,3,6,12,15 and 18 months from slices of brain indicate blue shift of the peak from younger to older ones(the peak wavelength shift from 600nm in young mice to 520 nm in the very old). Such blue shift is associated with decline in cognitive functions as the mice get old may suggest that the brain may transform to use relatively high energy biophotons for neural information processing during ageing.



In an interesting study the results have indicated that biphotonic activities induced by glutamate were significantly reduced and blue shifted in brain cells and synaptosomes in Alzheimer's and vascular dementia, the two major types of dementia.

REDSHIFT AND HIGH INTELLIGENCE LEVEL

Photon emissions in the brain are red shifted in intelligent species. Scientists studied the wavelengths of photons emitted by glutamate induced brain samples from increasing intelligent species- bullfrog, mice, chicken, pig, rhesus monkey and humans. The peak wavelength measured increases from 600nm in bullfrog to 865 nm in humans. Longer the wavelength the more intelligent is the species. This brain property may be a key biophysical basis for explaining high intelligence in humans because biophoton redshift could be more economical and effective measure of biophotonic signal communications and information processing from the human brain.

Pjotr Garjajev, a Russian scientist claims, he had managed to intercept communication from a DNA molecule in the form of UV photons. He further claimed to have captured this communication (light) from one organism (a frog embryo) and then transmitted it to another organism(salamander embryo) causing it to develop into a frog. He proposes that organisms use this light to talk to other organisms, suggesting a kind of telepathy. His claims are not widely accepted by main stream researchers in this field.

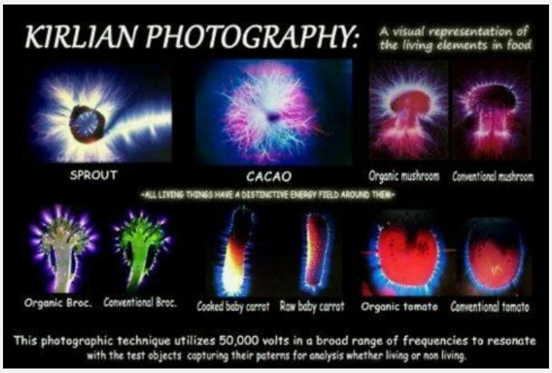
Table 1. Spectra in various species

Species (*N*)	λ_{aver}, nm
Bullfrog (5)	600.3 ± 0.82
Mouse (5)	646.9 ± 1.53***
Chicken (5)	667.3 ± 2.00***
Pig (34)	682.3 ± 0.68***
Monkey (11)	696.9 ± 0.85***
Human (31)	714.6 ± 1.59***
F value; *P* value	$F = 399$; $P < 0.0001$

EDIBLE PHOTONS

Edible biophotons are small photon emissions found in living foods, primarily in fresh, raw and organic plant foods. Foods rich in biophotons are thought to support cellular health and enhance vitality and healing. The highest forms of edible photons come from raw, fresh and organic fruits, vegetables, sprouts, herbs, leafy greens and wheat grass(juice). Cooking or processing foods diminishes their biophoton content.

Fruits raw, sun-ripened show high amounts of biophoton emission -berries, apples, grapes, mangoes, citrus fruits.



Fresh leafy greens and raw vegetables are highest in the biophoton content due to their high chlorophyll and sun exposure- spinach, lettuce, broccoli, cabbage. Sprouts and microgreens are some of the most biophoton rich foods.

Wheat grass juice is often highlighted for its high biophoton content. Fermented foods, if made from fresh ingredients retain photon energy due to life processes involved in fermentation

BIOPHOTONS IN THE FIELD OF MEDICINE

Biophoton measurements, being non-invasive, help in early detection of cancer, infection and inflammation. Tumour cells often show higher biophoton emission due to increased metabolic activity and mitochondrial dysfunction. Elevated emissions can reflect immune response or infection, suggesting use in inflammation assessment.

Any unusually strong or irregular glow might indicate heightened stress, inflammation or even signs of ageing, offering a completely non- invasive method of diagnosis.

Biophoton emission can be used to track the effectiveness of certain treatments, especially antioxidants, radiation therapy and chemotherapy. During radiation and chemotherapy, the malignant cells are destroyed or killed that leads to enhanced or bursts of biophoton emission.

Every 1K increase in body temperature increases metabolic rate by 10%. A mere increase in temperature of human body from 38 to 39deg.C, causes 1.5 to 2 times increase in the rate of emission. In case of hight fever the rate of emission increases to 3 times. In the regions of infection patchy increase is detected.

The experimental data support the hypothesis that human photon emission can be influenced by meditation. The photon emission from the subjects in meditation state is less compared to normal state.

The ultra weak light emitted by cells may hold valuable non-invasive diagnostic clues. Recent studies suggest that biophotons emission intensity and spectral characteristics can differ between healthy and diseased tissues, particularly in cases of cancer, neural degeneration and oxidative stress disorders. As such, researchers are exploring the biophoton analysis as a non- invasive diagnostic tool capable of detecting subtle changes in real time. Kobayashi, a bio scientist working in this field is trying to construct a biphotonic image of humans on lines of X-rays, EEG and MRI images.

Research has shown that biophoton emission rate can be influenced by various physiological processes, including heart activity, potentially shedding light on new diagnostic or monitoring tools. More studies are needed to fully understand this relationship.

BIOPHOTONS IN AGRICULTURE

In agriculture, biophoton measurements are being used to assess plant health and monitor stress response. The possibility that living systems emit meaningful light signals opens a promising avenue for bio imaging, environmental monitoring and early disease detection.

The biophoton characteristics such as the rate of photon emission is being considered a promising method for testing the quality of fresh Chinese herbs in traditional Chinese medicine (TCM).

CONCLUSION

The study of biophotons represents a fascinating frontier at the intersection of biology, physics, and consciousness. Once dismissed as experimental noise or fringe speculation, biophotons are now accepted as real, measurable phenomenon, even if their full significance remains unclear. The biphotonic emission from living organisms may turn out to be a silent but fundamental language of life, one that we are only beginning to decode. Whether biophotons become a cornerstone of medical diagnostics or remain a biological curiosity, they challenge us to rethink what it means for life to be " luminous". Whether the biophotons are deep echoes of metabolic rhythm (waste produced i.e. byproducts of metabolic reactions or carry information between cells and organisms) or subtle language of cellular communication, they remind us that life is radiant in ways we are only just beginning to understand. May be biophotons are "whispers of life". More research is needed to know if the biophotons are simply a metabolic 'waste light' or 'true information carrier".

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Professor of Physics (retd.)
& Former Principal, ASM College for Women, Ballary

ACTIVITIES OF KPA MEMBERS (from 1 September 2025)

1. Low-cost physics experiments were demonstrated to the students of Karnataka Public School at Hanagonahatti, Magadi Road, Bengaluru on 6 th September by Dr.B A Kagali and Prof.Liyakhat Ali Khan. It was jointly organized by Agastya Foundation and IAPT, RC 12 A Chapter.

2. Dr B S Srikanta spoke on ‘Journey from Classical Mechanics to Quantum Mechanics’, Dr Somasekara spoke about ‘the Foundational Principles of Quantum mechanics and Quantum Technologies’ and Dr.Oswalt Manoj of Alliance University spoke on ‘Artificial Intelligence and its Applications’ in a Seminar organized at RPA First grade College, Rajajinagar, Bengaluru on 8 th September 2025.

3. Dr. B A Kagali spoke on ‘Quantum Science and Technologies’ and Dr. K S Kiran spoke on ‘Quantum computation’ at LVD College, Raichur on 9th September 2025.

4. Dr. S M Khened spoke on ‘Quantum Science and Technology’ and Dr.K S Kiran spoke on ‘Quantum Computating’ at SMV College of Engineering, Raichur on 9 th September 2025.

5. Dr.B A Kagali spoke on ‘Introduction to Quantum Science and Technologies’, Dr.V M Jail spoke on ‘Smart Materials’, Dr. S M Hanagodimath spoke on ‘Nuclear energy’, Dr.K S Kiran Spoke on ‘Quantum Computating’, Dr. M S Jogad spoke on ‘Spin Glasses’ and Dr.K S Malleash spoke on the Principles of Classical and quantum mechanics’ at SB Science College, Kalaburagi on 10 th September 2025.

6. Dr. P Nagaraju spoke about Quantum Science and technology at Kwaja Bandenawaz University,Kalaburagi, 28th September 2025

7. Dr. Somasekara S. served as the primary resource person at a workshop for teachers at Thokkottu, Mangaluru on 6 th and 7 th October 2025. He delivered talks about the constructive approach to science teaching and learning. It was organized by A J Academy for Research and Development and Agastya Foundation.

8. Dr. M S Jogad, Dr. Paniveni Udayashankar and Dr. P Nagaraju presented their papers at the IAPT annual convention held at Goa University (4 – 6th October 2025).

9. Dr.Shantala V S delivered a talk on quantum science on 7-10-2025 at V D H school in Goa.

10. Dr. B S Srikanta delivered a talk on ‘Introduction to Quantum Mechanics’ and Dr. K S Kiran spoke on ‘Quantum computing’ at Seshadripuram Degree College, Bengaluru on 11th October 2025.

11. A workshop for PU College teachers and students was held on 7th August 2025 at Government PU College Hebbala. Dr B.A. Kagali, Dr B.S. Srikanta and Dr S. Somashekara served as resource persons.

12. A Quantum Science Awareness Programme was conducted at Kalburgi during 19-20 August 2025 for three International Schools Dr. M.S. Jogad, Dr S. Somsekara and Dr S.M. Khened.

Snapshots of Science

Seminar at RPA First Grade College (8 Sept 2025)

Talk at SMV Engineering College, Raichur by Dr Khened (9 Sept 2025)

Talk at LVD College, Raichur by Dr. Kagali (9 Sept 2025)

Talk at LVD College, Raichur by Dr Kiran (9 Sept 2025)

Workshop at Raichur on Quantum Science

Workshop at SB Science College, Kalaburagi (10 Sep.2025)

Dr. P Nagaraju at IAPT convention, Goa University (4 -6, Oct 2025)

Talk at Goa on Quantum Science on by Dr Shantala (7 Oct 2025)

Dr Paniveni at the Goa IAPT convention (4-6 Oct 2025)

Dr Jogad at Seminar on QS & QT in Bidar (10 Oct 2025)

LIST OF WEBINARS HELD (FROM 1 AUGUST 2025 to 31 October 2025)

Sl.No	Date	Speaker	Topic
1	03.08.2025	Dr.M K Rabinal	Electronics without Silicon
2	17.08.2025	Dr. Sudha	Quantum Science & Quantum Technology – a bird's eye view
3	24.08.2025	Dr. M S Sriram	Introduction to Indian Astronomy
4	31.08.2025	Dr.Vijaykumar Krishnamurty	Physics of Life
5	07.09.2025	Dr. Ajit singh	The terrestrial water cycle through a river system
6	29.09.2025	Dr. H C Manjunath	Super heavy elements
7	19.10.2025	Dr.Oswalt Manoj S.	Artificial Intelligence and its applications
8	26.10.2025	Dr.Amruth Ramesh Thelkar	Solar PV systems-construction, control and applications