KARNATAKA PHYSICS ASSOCIATION (R)

(Reg. No. DRB2/SOR/210/2021-2022)

Website: www.karphysics.org

KPA NEWSLETTER – 10   **FEBRUARY 2026**

Editors

Prof. B. A. Kagali (Chief Editor)

Prof. Somasekara Sidiginamale

Prof. P. Nagaraju

Prof. S. P. Basavaraju

Prof. M. R. Nandan

Contents

> **Attention Please**
> KPA members and other contributors are requested to submit their write-ups (in English or Kannada) for the next issue of the Newsletter, scheduled to be published in **May 2026**.

Editorial

As usual, this issue has a wide variety of articles as well as the regular features.

An expert on the Indian education system explains the faults in the system that do not produce great achievers.

The next article gives a very friendly introduction the various aspects of Artificial Intelligence – machine learning, deep learning and large language models – that should enable physics students easily appreciate what AI is.

One of the greatest minds of the twentieth century, namely, Stephen Hawking, tells us the way to look at life through his witty quotes.

How to measure photospheric helium abundance in cool giants is described in the next article by an astrophysicist from IIA.

Black holes, undoubtedly, are some of the most enigmatic and fascinating objects in the universe. The next article - at the popular level - gives a summary of their history, formation, types and properties.

The uncertainty principle of Heisenberg is one of the corner stones of quantum mechanics. You will find a brief history about it in the next article.

We have all seen fire. But what exactly is it? The next short article gives us the answers. It is present only if Oxygen is available.

We all enjoy learning and talking about life events of great scientists! The next article gives an account of selected events and habits of a few well known scientists.

Auroras are very common features of atmospheres in northern latitudes. You will find an account of their formation and properties can be found in the next article.

The article by an economics Nobel laureate gives very useful tips for students - in particular it recommends them to go for broad based education instead of specialised skills that may fetch quick jobs.

Brian May's incredible story- described in the next article – shows us the satisfaction and usefulness of pursuing a passion without demanding quick benefits.

Up next is a thought-provoking piece on the familiar candle, followed by a summary of the ICPE 2025 conference held at Ropar.

A summary of KPA activities during the past three months can be found next. A list of webinars held during the past three months can be found in the last article. Several interesting fillers can be found between articles for all to enjoy.

Feedback from the readers is most welcome as that would help us improve the content and style of the Newsletter. Many thanks are due to Dr Muktha B.Kagali for designing and editing the newsletter at a short notice, that too without any charge!

Chief Editor

An Expert Explains Why Indian Science Fails to Produce Nobel Laureates

The major problem remains that the current nature of academia is resistant to change and blocks visionaries. Until this system is dismantled and replaced with transparent hiring, merit-based funding, and visionary leadership, India will remain a land of potential, not of discovery.

India hasn't produced a Nobel laureate in science in almost a century now. The reason often cited for this predicament is that India doesn't spend enough on research. Indeed, public investment in R&D must rise to at least 3 per cent of the GDP, as current levels remain modest. But is money really the only, or even the main, problem?

Leadership that prioritises control over creativity has turned many temples of science into bureaucratic fortresses. So, is the government responsible for this stagnation, or is academia to blame as well?

The answer, unfortunately, points to a crisis of leadership and vision within the system. Even a tenfold increase in funding will not bring transformation unless institutions are led by visionary scientists in the spirit of Homi Bhabha and Vikram Sarabhai.

The primary problem: How scientists are hired

India has a large pool of talented scientists, yet many of them are unable to secure academic positions. At the same time, our institutions are filled with faculty engaged in poor, incremental research.

This raises some troubling questions: What criteria guide the hiring of scientists and faculty? Are they truly evaluated on quality and merit, or do connections, regional bias and patronage have an undue weight in these decisions? Is the faculty selection process transparent, fair, and merit-based, or are deep reforms needed to bring meaningful change?

The struggle does not end once a young scientist makes it to an institution. They often have to fight for every piece of equipment, every student, and every square foot of space. Valuable time which could be used for transformative research is instead expended on tackling internal politics and bureaucracy, particularly regional and disciplinary bias. By the time they are settled, the drive to dream big is often lost.

The race for publications, awards, not for breakthroughs

In Indian academia, success is measured not by the quality or impact of your discoveries, but by the number of papers published and awards/medals collected. With several national academies and societies annually distributing a range of fellowships, medals, and awards, scientists chase citations, committees, and ceremonies, not ideas. The system thus rewards visibility over value and conformity over innovation.

Scientists and researchers are often forced to participate in this race, willingly or otherwise. Those who opt out face real consequences, such as loss of funding, reduced visibility, and lack

of institutional support. As researchers chase citations and committees, their resources are allocated elsewhere instead of tackling hard problems that could lead to Nobel-level breakthroughs.

The way forward: Let the 'Gen Z' lead

The problem is not limited to policies, but their makers. Indian academia is led by intellectuals who talk reform but fear meaningful change. While the wisdom and experience of senior leaders are invaluable, progress requires partnership with younger leaders who bring fresh ideas, urgency, and a global perspective.

This presents an opportunity to tap into the "Gen Z" of Indian academia, scientists aged 40 to 50 years, who are accomplished internationally yet still brimming with energy, ambition, and courage. The time is nigh to open up at least half of the leadership positions, including Directors, Vice-Chancellors, Secretaries of DST/DBT/CSIR/DAE, and the Principal Scientific Advisor's office.

This would mirror the transformation led by pioneers like Homi Bhabha and Vikram Sarabhai in the early years of Indian science. This could prove to be transformative in India's road to meaningful scientific breakthroughs, which could open the road to a Nobel Prize.

In a nutshell, meaningful change in scientific research in India requires academia to reform and align with the government's vision of a self-reliant India.

CV Raman   Hargobhind Khorana   Subrahmanyan Chandrasekhar   Venkatraman Ramakrishnan

CV Raman, who won the Physics Nobel in 1930, is the lone Indian citizen to have won the prize. Hargobhind Khorana (1968 – Medicine), Subrahmanyan Chandrasekhar (1983 – Physics) and Venkatraman Ramakrishnan (2009 – Chemistry) are all researchers of Indian origin.
(Wikimedia Commons)

Indians nominated for Nobel Prizes in sciences

The problem is not limited to policies, but their makers. Indian academia is led by intellectuals who talk reform but fear meaningful change. While the wisdom and experience of senior leaders are invaluable, progress requires partnership with younger leaders who bring to its

SATYENDRA NATH BOSE

Discipline: Physics
Work: For his work in quantum statistics, developing Bose-Einstein condensate. Class of elementary particles called Bosons are named after him
No. of nominations: 7

G N RAMACHANDRAN

Discipline: Chemistr[y]
Work: On structural biology, including determination of thre[e] dimensional protein structures, a precursor to the work honoured by 2024 Chemistry Nobel
No. of nominations: 1

MEGHNAD SAHA

Discipline: Physics
Work: An astrophysicist, he developed the Saha equation, a basic tool in deciphering the electromagnetic spectrum of stars
No. of nominations: 7

HOMI J BHABHA

Discipline: Physics
Work: Well known as the father of India's atomic programme, he provided the first understanding of Bhabha scattering, the interaction between electrons and positrons
No. of nominations: 5

T R SESHADRI

Discipline: Chemistry
Work: For his work on structure and synthesis of some organic compounds in plants that impact their pigmentation and flavour
No. of nominations: 2

UPENDRANATH BRAHMACHARI

Discipline: Medicine or Physiology
Work: For his work on tropical diseases, particularly the discovery of a treatment for kala-azar, a disease caused by a protozoan parasite
No. of nominations: 6

credit, the government has, in recent years, launched commendable initiatives for fundamental and translational research, start-ups, and innovation. At the same time, the government must continue to expand investment in research, aiming for 3% of GDP, and foster the inclusion of younger academic leaders who can drive this transformation with urgency and creativity.

The major problem remains that the current nature of academia is resistant to change and blocks visionaries. Until this system is dismantled and replaced with transparent hiring, merit-based funding, and visionary leadership, India will remain a land of potential, not of discovery.

Author
Vivek Vijayrao Polshettiwar, Professor of Chemistry
Tata Institute of Fundamental Research, Mumbai

******

The question is not why India has fewer Nobel laureates. The real question is: how many future Nobel-worthy ideas were never allowed to fail, wander, or mature?

We have produced brilliant students for the world, but we have not yet built a system that allows brilliance to stay, struggle, and succeed at home.

A senior Indian scientist once remarked that in his laboratory,

"A student is punished for failing an experiment, but never rewarded for asking a bold question."

A nation that celebrates examinations more than experimentation should not be surprised when discovery becomes rare."

Artificial Intelligence, Machine Learning, Deep Learning, and Generative AI — Clearly Explained

This article is for you if you want to know:

• How are Machine Learning and Deep Learning connected?
• What makes Generative AI different?

The objective here is clarity — not simplification through approximation, but accurate explanation in plain language.
No technical background is required for the rest of the article.
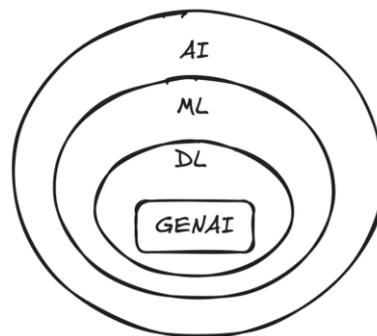
Figure 1 — AI Ecosystem
(created by the author using Excalidraw)

A useful way to understand the relationship between Artificial Intelligence, Machine Learning, Deep Learning, and Generative AI is to imagine Matryoshka dolls.

• Each concept contains the next one inside it:
• Nothing replaces what came before,
• Each layer builds upon the previous one.

Let's open them one by one.

Artificial Intelligence: the outer shell

Artificial Intelligence (AI) is the broadest definition.

At its core, AI refers to systems designed to perform tasks that typically require human intelligence.

In practice, AI includes systems that can:

1. Make decisions.
   Example: A navigation system choosing the fastest route based on real-time traffic conditions.
2. Draw conclusions.
   Example: A system deciding whether to approve or reject a loan application based on multiple factors.
3. Recognize patterns.
   Example: Detecting fraudulent credit card transactions by identifying unusual spending behaviour.
4. Predict outcomes.
   Example: Estimating future energy consumption or product demand.

Rule-based AI: intelligence written by humans

In the early decades of AI, particularly in the 1970s and 1980s, systems were primarily rule-based.

What I mean is that humans explicitly wrote the logic.
The computer did not learn — it executed predefined instructions.

• -> A rule looked like this in human natural language:
"If a house has at least three bedrooms and is located in a good neighbourhood, then its price should be around €500,000."

• -> In programming terms, the logic is similar but written in code with something that can looks like this:

IF bedrooms ≥ 3 AND neighbourhood = "good"
THEN price ≈ 500000

This was considered Artificial Intelligence because human reasoning was encoded and executed entirely by a machine.

Why rule-based AI was limited

Rule-based systems work well only in controlled environments.

Real-world conditions are not controlled. If we are still with our real estate example.

• markets evolve,
• contexts change,
• exceptions multiply.

The system cannot adapt unless a human rewrites the rules.
This limitation led to the next layer.

Machine Learning: letting data speak

Machine Learning (ML) is a subset of Artificial Intelligence.

The key shift is simple but profound:

Instead of telling the computer what the rules are, we let the system learn them directly from examples.

-> Let's return to the house price example. Instead of writing rules, we collect data:

• surface area,
• number of rooms,
• location,
• historical sale prices.

Surface.	nb_rooms	Location	Price
50	2	Area1	100000
180	6	Area2	700000
200	7	Area1	300000
15	1	Area3	130000
45	2	Area2	100000
60	3	Area4	320000
⋮	⋮	⋮	⋮

Table 1 — Example of Data
(created by the author using Excalidraw)

Thousands, sometimes millions, of past examples.
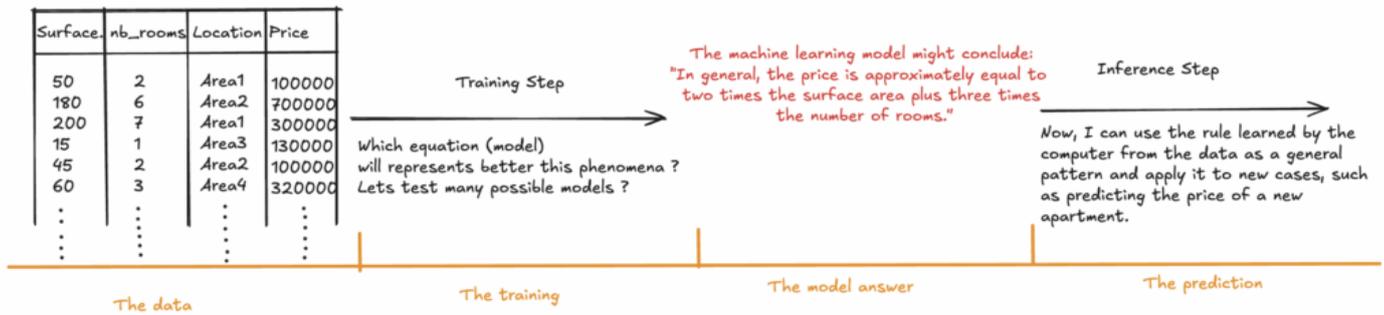This data is provided as training data to a machine learning model.

Figure 2 — Machine Learning Pipeline
(created by the author using Excalidraw)

But what does "training a model" using data actually mean?

Training is not a black box.

We begin by choosing a mathematical model — essentially an equation — that could describe the relationship between inputs (surface, location, etc.) and output (price).

We do not test one equation. We test many (We call them models).

A very simplified example might look like:

price = 2 × surface + 3 × location

The model adjusts its parameters by comparing prices with real prices across many examples.

No human could manually analyse hundreds of thousands of houses at once. A machine can.

How do we know a model works?

Before adopting a model — that is, the equation that best represents the phenomenon we are studying — we evaluate it.

Part of the data is intentionally hidden. This is known as test data.

The model:
- Never sees this data during training,
- Must make predictions on it afterward.
- Predictions are then compared to reality
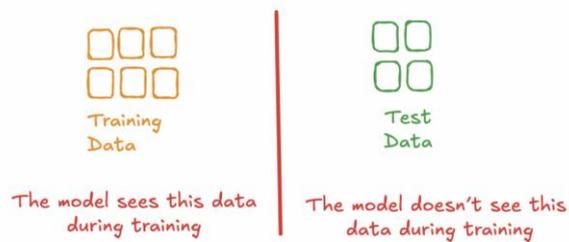
Figure 3 — Train/Test Data
(created by the author using Excalidraw)

If performance is good on unseen data, the model is useful.

If not, it is discarded and another model is tried.

This evaluation step is essential.

Machine learning excels at tasks humans struggle with:

• Analysing large volumes of data,
• Detecting subtle patterns,
• Generalizing from past examples.

Examples of applications:

1. Healthcare
   -> disease risk prediction,
   -> analysis of medical images.
2. Industry
   -> predicting equipment failures,
   -> optimizing production processes.
3. Consumer products
   -> recommendation systems,
   -> fraud detection.

The limits of traditional machine learning

Nevertheless, traditional Machine Learning has important limitations.

It works very well with structured data:

• tables,
• numerical values,
• clearly defined variables.

However, it struggles with types of data that humans handle naturally, such as:

• images,
• audio,
• text.

The reason for this limitation is fundamental -> "computers only understand numbers"

Computers do not understand images, sounds, or words the way humans do. They only understand numbers.

When working with images, text, or audio, these data must first be transformed into numerical representations.

For example, an image is converted into a matrix of numbers, where each value corresponds to pixel information such as colour intensity.

Only after this conversion can a machine learning model process the data.

This transformation step is mandatory.

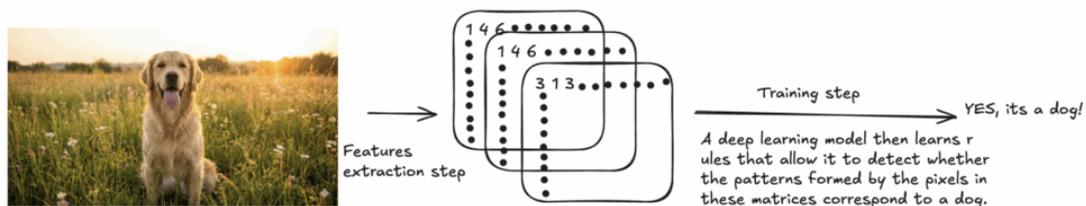Figure 4 — Converting an Image to Matrices
(created by the author using Excalidraw)

Feature extraction: the traditional approach

Before the rise of deep learning, this transformation relied heavily on manual feature engineering.

Engineers had to decide in advance which characteristics might be useful:

• edges or shapes for images,
• keywords or word frequencies for text,
• spectral components for audio.

This process, known as feature extraction, was:

• time-consuming,
• fragile,
• strongly dependent on human intuition.

Small changes in the data often required redesigning the features from scratch.

Why deep learning was needed

The limitations of manual feature extraction in complex settings were a key motivation for the development of Deep Learning.

(I'm not covering the more technical motivations in this article. My goal is to give you a clear understanding of the big picture).

Deep Learning does not eliminate the need for numerical data.

Instead, it changes how features are obtained.

Rather than relying on hand-crafted features designed by humans, deep learning models learn useful representations directly from raw data.

This marks a structural shift.

Deep Learning: the structural shift

Deep Learning still works as Machine Learning.

The learning process is the same:

-> data,
-> training,
-> evaluation.

What changes is what we call the architecture of the model.

Deep learning relies on neural networks with many layers.

Layers as progressive representations
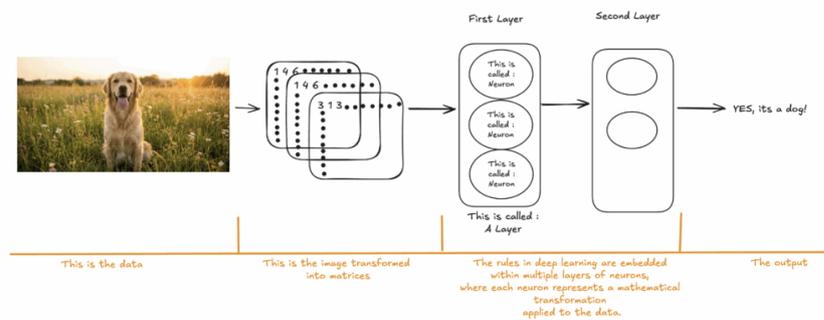
Figure 5 — Deep Learning Pipeline
(created by the author using Excalidraw)

Each layer in a deep learning model applies a mathematical transformation to its input and passes the result to the next layer.

These layers can be understood as progressive representations of the data.

In the case of image recognition:

• Early layers detect simple patterns such as edges and contrasts,
• intermediate layers combine these patterns into shapes and textures,
• later layers capture higher-level concepts such as faces, objects, or animals.

The model does not "see" images the way humans do.

It learns a hierarchy of numerical representations that make accurate predictions possible.

Instead of being told explicitly which features to use, the model learns them directly from the data.

This ability to automatically learn representations is what makes deep learning effective for complex, unstructured data.

And once this level of understanding is reached, an important shift becomes possible.

Up to this point, deep learning models have mainly been used to analyse existing data.

They are trained to: Never sees this data during training,
                        Must make predictions on it afterward.
                        Predictions are then compared to reality

• recognize what is present in an image,
• understand the structure of a text,
• classify or predict outcomes based on learned patterns.

In short, they help answer the question: What is this?

But learning rich representations of data naturally raises a new question:

If a model has learned how data is structured, could it also produce new data that follows the same structure?

This question is the foundation of Generative AI.

Generative AI: from analysis to creation
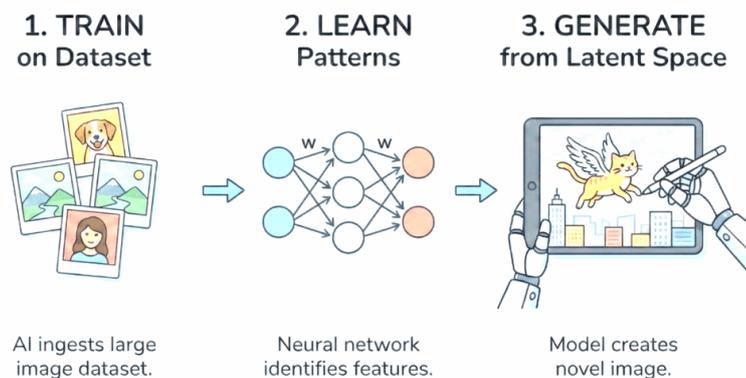
Figure 6 — GenAI Pipeline
(created by the author using Gemini3)

Generative AI does not replace deep learning. It builds directly on top of it.

The same deep neural networks that learned to recognize patterns can now be trained with a different objective: generation.

Instead of focusing only on classification or prediction, generative models learn how data is produced, step by step.

As a result, they are able to create new content that is coherent and realistic.

A concrete example

Consider the prompt:

"Describe a luxury apartment in Paris."

The model does not retrieve an existing description.

Instead:

• It starts from the prompt,
• predicts the most likely next word,
• then the next one,
• and continues this process sequentially.

Each prediction depends on:

• What has already been generated,
• The original prompt,
• And the patterns learned from large amounts of data.

The final text is new — it has never existed before — yet it feels natural because it follows the same structure as similar texts seen during training.

The same principle across data types

This mechanism is not limited to text.

The same generative principle applies to:

• images,
• audio,
• video,
• code.

This is why these models are often called foundation models: a single trained model can be adapted to many different tasks.

Why Generative AI feels different today

Artificial Intelligence, Machine Learning, and Deep Learning have existed for many years.

What makes Generative AI feel like a turning point is not only improved performance, but how humans interact with AI.

In the past, working with advanced AI required:

• technical interfaces
• programming knowledge,
• infrastructure and model management.

Today, interaction happens primarily through:

• natural language,
• simple instructions,
• conversation.

Users no longer need to specify how to do something.

They can simply describe what they want.

This shift dramatically reduces the barrier to entry and allows AI to integrate directly into everyday workflows across a wide range of professions.

Putting everything together

These concepts are not competing technologies.

They form a coherent progression:

• Artificial Intelligence defines the goal: intelligent systems.
• Machine Learning enables systems to learn from data.
• Deep Learning allows learning from complex, unstructured information.
• Generative AI uses this understanding to create new content.

Seen this way, Generative AI is not a sudden break from the past.

It is the natural continuation of everything that came before.

Once this structure is clear, AI terminology stops being confusing and becomes a coherent story.
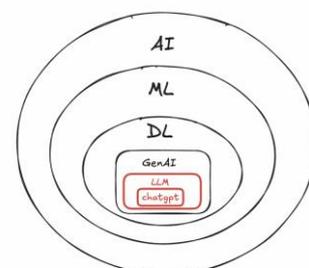
But, have we finished? Almost.

Figure 7— The Complete AI Ecosystem in 2025
(created by the author using Excalidraw)

At this point, we've covered the core AI ecosystem: artificial intelligence, machine learning, deep learning, and generative AI — and how they naturally build on one another.

If you are reading this article, there is a good chance you already use tools like ChatGPT in your daily life.

I won't go much deeper here — this deserves an article of its own.

However, there is one important final idea worth remembering.

Earlier, we said that Generative AI is a continuation of Deep Learning, specialized in learning patterns well enough to generate new data that follows those same patterns.

That is true — but when it comes to language, the patterns involved are far more complex.

Human language is not just a sequence of words.

It is structured by grammar, syntax, semantics, context, and long-range dependencies.

Capturing these relationships required a major evolution in deep learning architectures.

From Deep Learning to Large Language Models

To handle language at this level of complexity, new deep learning architectures emerged.

These models are known as Large Language Models (LLMs).

Instead of trying to understand the full meaning of a sentence all at once, LLMs learn language in a very particular way:

They learn to predict the next word (or token) given everything that comes before it.

This might sound simple, but when trained on massive amounts of text, this objective forces the model to internalize:

• grammar rules,
• sentence structure,
• writing style,
• facts,
• and even elements of reasoning.

By repeating this process billions of times, the model learns an implicit representation of how language works.

From these Large Language Models, conversational systems such as ChatGPT are built — combining language generation with instruction-following, dialogue, and alignment techniques.

The illustration above shows this idea visually: generation happens one word at a time, each step conditioned on what was generated before.

The final big picture

Nothing you see today came out of nowhere.

ChatGPT is not a separate technology.

It is the visible result of a long progression:

• Artificial Intelligence set the goal.
• Machine Learning made learning from data possible.
• Deep Learning enabled learning from complex, unstructured data.
• Generative AI made creation possible.
• Large Language Models brought language into this framework.

I hope this article was helpful. And now, you're no longer lost in tech conversations — even at your end-of-year family gatherings.

If you enjoyed this article, feel free to follow me on LinkedIn for more honest insights about AI, Data Science, and careers.

LinkedIn: *Sabrine Bendimerad*
Medium: https://medium.com/@sabrine.bendimerad1
Author:
Sabrine Bendimerad

Stephen Hawking's Quotes That Will Change How You See Life

Stephen Hawking, one of the greatest mind of our time, often challenged us to rethink our perspectives, embrace the unknown, and live with purpose.

"However difficult life may seem, there is always something you can do and succeed at."

(Hawking reminds us that no matter how challenging life feels, there's always a path forward. It is a call to focus on what you can control, rather than being paralyzed by what you cannot.)

"Intelligence is the ability to adapt to change."

(Life is unpredictable, and challenges are inevitable. Hawking emphasizes that true intelligence isn't just book smarts—it's resilience and flexibility. The ability to adjust your mind set, strategies, and expectations is crucial for growth, survival, and success.)

"Life would be tragic if it weren't funny."

(Even in the darkest moments, Hawking found humour as a way to cope. This quote reminds us that laughter and light heartedness are essential for resilience. Humour can provide perspective, lighten burdens, and make life's difficulties more bearable.)

"People won't have time for you if you are always angry or complaining."

(Hawking underscores the importance of a positive, proactive attitude. Complaining or dwelling on negativity drains energy and pushes others away. Instead, focus on solutions, curiosity, and optimism—it attracts support and builds meaningful connections.)

"Remember to look up at the stars and not down at your feet."

(A call to maintain perspective. Even when life's challenges weigh us down, keeping an eye on the bigger picture—curiosity, wonder, and the universe around us—can inspire hope, creativity, and a sense of purpose. It's about dreaming big and seeking meaning beyond immediate struggles.)

"We are just an advanced breed of monkeys on a minor planet of a very average star. But we can understand the universe. That makes us something very special."

(Hawking highlights both humility and empowerment. While humans are small in the cosmic scale, our ability to reason, explore, and understand the universe gives life meaning. It's a reminder to value our potential and use it to expand knowledge, curiosity, and creativity.)

"However bad life may seem, there is always something you can do."

(Similar to his first quote, Hawking reinforces that life is never entirely hopeless. Action, no matter how small, can create momentum and change. It's a reminder to focus on what's possible rather than being overwhelmed by challenges.)

"Work gives you meaning and purpose, and life is empty without it."

(Hawking believed that staying mentally and physically engaged is vital for fulfilment. Work—whether it's professional, creative, or personal projects—keeps us focused, motivated, and connected to the world. Without it, even life's comforts can feel hollow.)

Curated by: Nisha Dubey
Edited by: Bhaswati Sengupta

*****

The Universe Did Not Know He Was Ill

When Stephen Hawking was a young graduate student at Cambridge, he was once asked why he continued to work so intensely despite knowing that his illness would slowly take away his ability to move and speak.

Hawking smiled and replied that 'the universe did not know he was ill'. The stars still moved, time still curved, and questions still waited to be answered.

So every day, even as his body weakened, he chose to think harder— not to defeat death, but to honour curiosity. In time, those thoughts changed how humanity understood black holes and the origin of the universe.

Measuring Photospheric Helium Abundance in Cool Giants

The study of chemical abundances on a star's surface is an effective method for uncovering its complete history of origin and evolution. In stars, hydrogen and helium are the most abundant elements, and the fusion reactions occurring in their interiors change the abundances of all other elements throughout the evolutionary process.

Because hydrogen and helium are so abundant their abundances cannot be measured directly. For normal stars that are rich in hydrogen, a standard value of 10^{12} hydrogen atoms is typically adopted. All other elemental abundances are measured relative to this standard value from their observed spectral lines of atomic and molecular absorption.

Due to the requirement of a warmer effective temperature (greater than 10,000 K) to excite the helium atoms, the abundance of helium cannot be directly measured from helium lines in cooler stars. Instead, observations of helium lines in warmer or hotter stars allow us to estimate the helium-to-hydrogen (He/H) ratio, which is about 0.1.

In our study, we examined the absorption band of magnesium hydride (MgH) and the neutral magnesium (Mg I) lines to determine the actual helium abundance in cool stars. For a given star, the magnesium abundance derived from different features such as MgH and Mg I should be the same. However, the difference in the magnesium abundance derived from MgH compared to that from Mg I for the star can indicate any changes in the abundance of hydrogen or helium, as these are relative.

If there is reduction in hydrogen, there will be a corresponding enhancement in helium.

Some stars in the universe exhibit peculiar elemental abundances that differ from what is typically expected. One key element among these is lithium. Lithium is a fragile element that gets destroyed even at lower temperatures, so measuring its abundance on the stellar surface provides crucial information about the evolutionary phase of a star.

Once stars complete their main-sequence phase they evolve into red giants. During this transition, the star brings material from its interior layers to the surface through the dredge-up process. As a star enters the red giant phase, its

original lithium abundance becomes diluted, leading to a surface that is typically devoid of lithium.

However, about 1% of red giants are found to be lithium rich, possessing up to 1000 times more lithium than what is observed in the Sun, a main-sequence star.

Several processes may be responsible for this lithium enrichment in giant stars. These could include the preservation of the pristine material from which the star was formed, new lithium production, or contributions from external sources, such as the engulfment of lithium-rich planets.

In lithium-rich giants, if lithium is brought to the surface during the dredge-up process on the giant branch, it should also be accompanied by helium and other hydrogen-burning products, such as ^{13}C (an isotope of carbon) and nitrogen.

Our sample comprises 18 red giants and 2 supergiants. This study is based on high-resolution spectra primarily obtained from the Himalayan Chandra Telescope (HCT), Hanle, India, as well as from archives of various telescopes worldwide. The data reduction and analyses were carried out using standard procedures.

Our analyses involve the determination of star's effective temperature and surface gravity which in turn allows us to derive the elemental abundances. For the adopted model atmospheres with a standard He/H ratio, the abundances of approximately 23 elements were derived for each program star.

The standard adopted helium-to-hydrogen (He/H) ratio is 0.1, that is abundance of helium is one tenth of hydrogen. For stars that exhibit a significantly different magnesium (Mg) abundance derived from atomic and molecular lines, as discussed previously, the He/H ratio may be nonstandard.

To analyze this a set of model atmospheres were computed for the derived stellar parameters and for various nonstandard He/H ratios, such as 0.2, 0.3, 0.4, etc.

By adopting the corresponding Mg abundance derived from the Mg I lines for a program star, the MgH band was synthesized for different He/H ratios. By obtaining the best fit to the observed MgH band the He/H ratio for a program star is derived (as illustrated in Figure 1). This indicates that adoption of a model atmosphere with appropriate He/H ratio should yield consistent Mg abundances from both MgH and Mg I lines.

Out of 20 program stars, six have a higher He/H ratio than the standard value of 0.1 (see Figure 2). Among these six giants, five are red giants and one is a supergiant.

Our sample includes stars with a range of lithium abundances, from low to high ($-1.0 < \log \varepsilon(\text{Li}) < 4.55$ dex). Interestingly, the five red giants with enhanced He/H ratios also exhibit higher lithium abundances, except for the supergiant. This observation clearly suggests a correlation between helium and lithium levels.
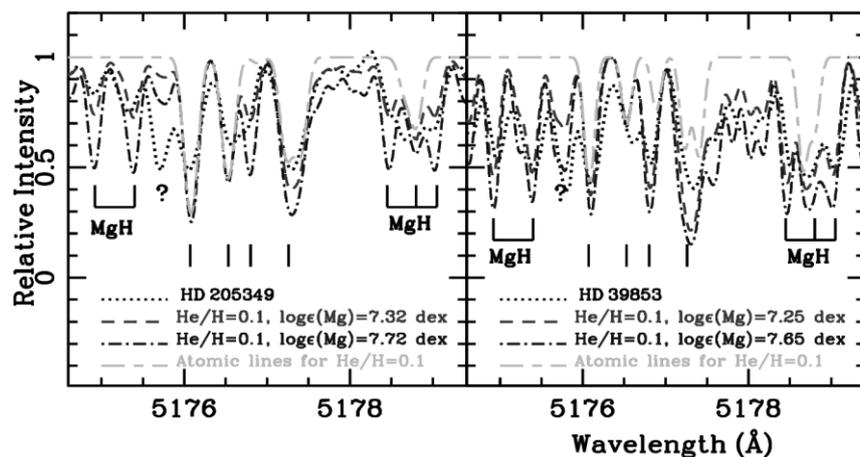

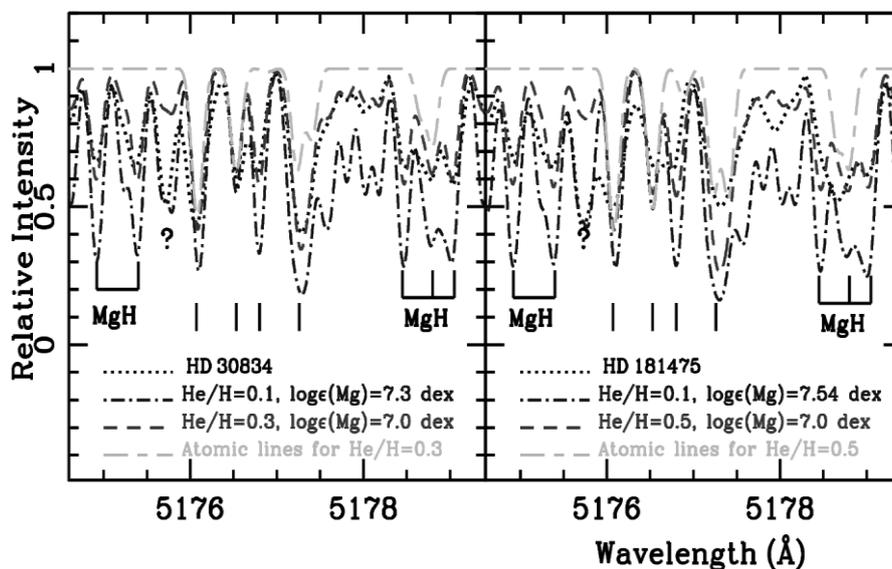Figure 1. The observed and the synthetic spectra of the MgH band for normal program stars (He/H = 0.1).

Figure 2. The observed and the synthetic spectra of MgH band for the He-enhanced (He/H > 0.1) stars.

The main discovery of this work is that all helium-enhanced red giants are also super-rich in lithium, with an exception of the supergiant star (see Figure 3). However, not all lithium-rich giants exhibit helium enhancement.

This indicates that the photospheric helium enrichment is accompanied by the lithium enrichment in the giants, as we envisaged.

Our lithium-rich sample stars evince that two or more processes, at least, are responsible for lithium enrichment in giants: one that enriches only lithium, and another that enriches both helium along with lithium.

Interestingly, our results show that helium enhancement is not limited to a specific phase of the giant branch but occurs throughout it.

One plausible explanation for the simultaneous enrichment of helium and lithium in giants is the internal synthesis of lithium, which is then dredged up along with helium from deeper layers to the surface. However, there could be multiple scenarios operating in tandem.

This study represents the first spectroscopic measurement of photospheric helium abundance in both normal and lithium-rich field giants.
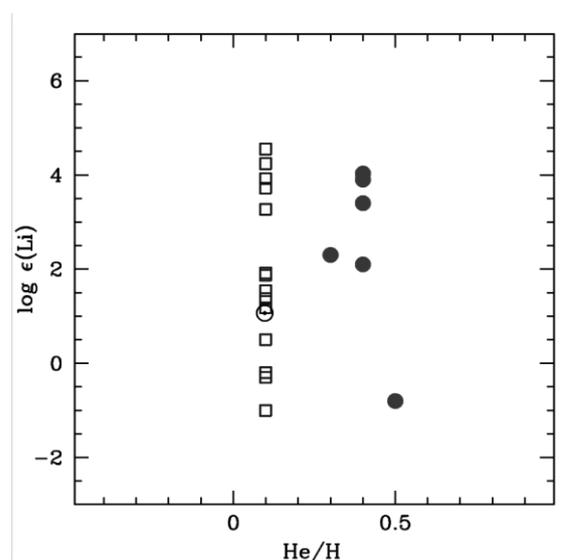

Figure 3. The lithium-abundance, log ε(lithium), for the program stars vs. the (He/H). The open blue squares are the stars with normal He/H ratios (He/H = 0.1) and the filled red circles are the He-enhanced ones (He/H > 0.1).

This research has been published in the *Astrophysical Journal (ApJ)* of the American Astronomical Society (AAS) as a paper titled, "Photospheric Helium

Abundance in Cool Giants: A Comprehensive Study", authored by Hema B. P. and Gajendra Pandey, Indian Institute of Astrophysics, India.

For details, please visit:
https://iopscience.iop.org/article/10.3847/1538-4357/adea40

This research publication has been highlighted in the press release by the Department of Science and Technology, Government of India.

For details, please visit:
https://dst.gov.in/astronomers-unearth-unexpected-chemical-link-during-stellar-evolution
https://www.pib.gov.in/PressReleasePage.aspx?PRID=2190008

For queries, please reach out to the author:
hemabp.phy@gmail.com / hema.bp@iiap.res.in
Author:
Dr. Hema B.P., IIA

<div align="center">******</div>

The Secret of Quiet Stars

One day in a classroom discussion on cool giant stars, a student raised a hand and asked with genuine curiosity,

"Sir, if helium is present in these huge stars, why is it so difficult to measure?"

The professor paused, smiled, and looked at the spectral lines on the board before replying,

"Not all stars like to tell their stories out loud. Some prefer to keep their secrets—especially the quiet ones."

The class laughed softly.
But the lesson stayed with them:
in science, some truths do not reveal themselves easily; they must be patiently listened for.

The Theory and Observation of Black Holes – an Introduction

The following is a brief account of some of the most exotic objects in the universe called 'black holes', starting with wild speculations about their existence to their direct 'imaging' in recent times using highly specialised telescopes.

In 1783 English Clergyman John Michell applied the concept of escape velocity -the speed required for an object to escape a star's gravity – to light particles (corpuscles). He reasoned that if a star was sufficiently massive and compact, its escape velocity would be greater than the speed of light. He correctly concluded that if a star's light could not "arrive at us," the object would be invisible. Michell calculated that a star with the same density as the Sun but with a radius 500 times larger would be a dark star. He proposed a method for detecting these invisible objects: observing the gravitational effects on a visible companion star in a binary system. This method is precisely how astronomers today identify many black hole candidates, such as Cygnus X-1. Michell also suggested that the surface gravity of stars could be measured by observing a "diminution of the velocity of their light," which foreshadowed the modern concept of gravitational redshift, a prediction of Einstein's theory of general relativity.

Michell's ideas were far ahead of their time and, due to the prevailing view of light as a wave in the 19th century, were largely forgotten until his paper was rediscovered in the 1970s. His work is now recognized as the first theoretical prediction of objects with the characteristics of black holes.

In his 1796 book Exposition du Système du Monde, French mathematician Pierre Laplace briefly suggested that a sufficiently large and massive star would have a surface escape velocity that exceeded the speed of light, making it invisible to distant observers. He noted, "It is therefore possible that the greatest luminous bodies in the universe are on this account invisible".

Like Michell, Laplace's theory was based on Newtonian mechanics, which correctly predicted that gravity would affect light particles and that a critical escape velocity could be calculated. Theirs were remarkable intellectual achievements, even though the underlying physical theory (Newtonian gravity) was later replaced by Einstein's General Relativity for a full description of black holes.

The core principle of general 'elativity formulated by Albert Einstein in 1915 is that mass and energy 'warp' the fabric of space and time, and this curvature is

what we perceive as gravity. Black holes represent the most extreme manifestation of this warping!

In 1916, just months after Einstein published his theory, the physicist Karl Schwarzschild found the first exact solution to Einstein's field equations for a spherical, non-rotating mass. This solution included a critical radius – now called the Schwarzschild radius -where the gravitational pull becomes so intense that the escape velocity exceeds the speed of light—the defining characteristic of a black hole's event horizon.

Einstein viewed the "singularities" (points where the equations seemed to break down) in the Schwarzschild solution as a mathematical oddity or a pathology of the coordinates used, rather than a description of a real physical object. In a 1939 paper, he even tried to prove that natural processes, like a collapsing star's particles moving faster than light, would prevent a black hole from ever forming!

Ultimately, while Einstein was a "reluctant father" of the concept of black holes; his ground-breaking theory was the very tool that allowed later generations of scientists to theoretically predict and, eventually, observationally confirm the existence of black holes. Modern observations, such as the first image of a black hole in 2019 and the detection of gravitational waves from black hole mergers in 2015, continue to validate general relativity in these extreme environments.

Chandrasekhar's speculation

During a sea voyage in 1930, while still a young student, he performed calculations using quantum mechanics and special relativity that revealed a crucial limit for the maximum mass of a stable white dwarf star. This limit, now known as the 'Chandrasekhar Mass Limit', is approximately 1.44 times the mass of the Sun. Chandrasekhar theorized that any star remnant with a mass below this limit would cool and become a stable white dwarf.

For stars with a final mass above this limit, the internal electron degeneracy pressure (which keeps white dwarfs from collapsing) would be insufficient to counteract gravity. He concluded that such massive stars would continue to collapse indefinitely under their own gravity, eventually shrinking into objects so dense that nothing, not even light, could escape. These were the theoretical precursors to what we now call black holes.

His ideas were initially met with strong scepticism and public ridicule from the prominent astrophysicist Sir Arthur Eddington, which delayed their general acceptance for decades.

Oppenheimer's demonstration

In their landmark 1939 paper, "On Continued Gravitational Contraction," J. Robert Oppenheimer and his student Hartland Snyder used Einstein's theory of general relativity to predict for the first time how a black hole could form naturally from the collapse of a massive star. Their work provided a concrete, mathematical model for what had previously been considered only a theoretical curiosity.

They developed a theoretical model (now called the Oppenheimer-Snyder model) that described the dynamics of a spherically symmetric, pressure-free star (composed of "dust") as it exhausted its nuclear fuel and began to collapse under its own gravity. They demonstrated that as the star's surface shrinks past a critical radius (the Schwarzschild radius), the star cuts itself off from any communication with the outside universe. No light or information from within this boundary can escape, effectively establishing the physical meaning of the' event horizon'.

For an observer on the surface of the collapsing star, the collapse to a central point (singularity) would take a finite, relatively short amount of time (mere hours for a sun-sized star). However, for a distant observer, the star's collapse would appear to slow down and its light would be red shifted as it approached the event horizon, seemingly frozen just at the boundary for an infinite amount of time.

The paper transformed the concept of a black hole from a mere mathematical curiosity (which even Einstein doubted could exist in nature) into a real, physical possibility and a generic outcome of the end stage of a massive star's life.

Their work laid the essential theoretical groundwork for the modern study of black holes. Physicists such as Roger Penrose, who later proved that black hole formation was a generic consequence of general relativity, built directly upon the Oppenheimer-Snyder model.

Formation of black holes

A star with an initial mass of at least eight times that of the Sun fuses lighter elements (hydrogen into helium, then helium into carbon, and so on) in its core, generating an outward pressure that balances the inward pull of gravity. This process continues through a sequence of elements until the core is primarily composed of iron. Fusing iron, unlike lighter elements, consumes energy rather than releasing it, meaning the energy production in the core abruptly stops. Without the outward pressure from fusion to support it, the iron core collapses almost instantly under its own extreme gravity. The matter is crushed into an incredibly dense state.

The collapse halts when the core reaches nuclear densities, causing it to effectively "bounce" and generate a powerful shock wave that blasts the star's outer layers into space in a brilliant explosion called a supernova. The fate of the remaining core depends entirely on its mass after the explosion: If the core's mass is below about 2 to 3 times the mass of the Sun (the Oppenheimer-Volkoff limit), it stabilizes as a 'neutron star'. If the core's mass exceeds this limit, no known force or pressure (not even neutron degeneracy pressure) can stop the continued collapse. The core collapses completely into an infinitely dense point called a singularity, surrounded by an event horizon, thus forming a stellar black hole. The resulting stellar black hole typically has a mass ranging from a few to several tens of solar masses.

The Discovery of Cygnus X-1

Astronomers first detected in 1964 Cygnus X-1 as a powerful source of X-rays using a sounding rocket launched by NASA. X-rays do not penetrate Earth's atmosphere, so space-based instruments were necessary for this discovery. At the time, the nature of the source was a mystery. Using the Uhuru X-ray satellite, scientists in 1971 determined that the X-rays were coming from a specific, small region of space.

British astronomers Louise Webster and Paul Murdin, and independently Canadian astronomer Charles Thomas Bolton, then used optical telescopes to identify a visible companion star in that exact location: a blue supergiant star called HDE 226868.

By studying the orbital motion and Doppler shifts of the visible star, astronomers calculated the mass of its unseen companion using Newtonian dynamics. The calculations indicated that the invisible object had a mass of at least several times that of the Sun (modern estimates place it around 21 solar masses).That mass was significantly higher than the theoretical maximum mass for a neutron star (the densest known objects at the time, apart from black holes). Therefore, the unseen object could not be a normal star, white dwarf, or neutron star.

The rapid and irregular flickering of the X-rays (on timescales as short as milliseconds) further suggested a very small, compact object, consistent with matter swirling into a black hole's accretion disk before crossing the event horizon.

By 1973, the astronomical community generally reached a consensus that Cygnus X-1 was indeed a black hole, providing the first observational evidence for these

extreme objects. The theoretical physicist Stephen Hawking lost a bet on it when he projected that it was not a black hole!

While astronomers estimate there are as many as 100 million stellar black holes in the Milky Way galaxy alone, only around 50 have been confirmed or regarded as strong candidates through direct observation methods, such as X-ray binaries or gravitational lensing. The vast majority are invisible because they do not have a companion star to pull gas from and thus do not emit detectable radiation (like X-rays).

Penrose's theorem

British mathematician Roger Penrose made fundamental contributions to black hole physics by providing a rigorous mathematical proof that their formation is an inevitable and robust consequence of Einstein's general theory of relativity, a discovery for which he was awarded the Nobel Prize in Physics in 2020.

In a ground breaking 1965 paper, Penrose introduced new mathematical methods (specifically, using topology and a concept called a "trapped surface") to prove that once a massive star collapses beyond a certain point, a singularity (a point of infinite density and zero volume where the known laws of physics break down) is unavoidable, even in realistic, imperfectly symmetrical scenarios. This challenged the belief held by many, including Einstein himself, that singularities were merely mathematical artefacts.

Penrose was instrumental in defining a black hole as a region of space and time from which it is impossible to escape to a large distance, which is now the generally accepted definition of an event horizon.

Because his theorems showed that singularities are a generic feature of general relativity, Penrose proposed the "cosmic censorship hypothesis," which conjectures that all singularities in nature must be hidden behind an event horizon (a black hole), thus preventing the exposure of 'naked' singularities.

He developed a graphical method, now called Penrose diagrams, to map the causal structure of spacetime around black holes, allowing physicists to visualize the effects of gravity on light and matter in these extreme environments.

Supermassive black holes (SMBHs)

These are the largest type of black holes, with masses ranging from hundreds of thousands to billions of times the mass of the Sun. They are found at the centers of nearly all large galaxies, including our own Milky Way galaxy, which hosts the SMBH known as Sagittarius A*. They are defined by their extraordinary

mass, typically between 100,000 and billions of solar masses. They reside in the galactic center of their host galaxy.

When actively feeding on surrounding gas and dust, SMBHs can become some of the brightest objects in the universe. The material forms a superheated, swirling 'accretion disk' that emits vast amounts of radiation (from radio waves to X-rays), often outshining the entire galaxy. These active SMBHs are referred to as Active Galactic Nuclei, or quasars if they are very distant and luminous. Powerful magnetic fields around active SMBHs can launch high-speed jets of plasma and energy away from the poles of the accretion disk, sometimes extending for hundreds of thousands of light-years.

The exact formation mechanism for the earliest "seed" SMBHs is still an active area of research, but once formed, they grow primarily in two ways: They consume massive amounts of gas and dust from their surrounding galaxy. They can merge with other black holes when galaxies collide, which is thought to be a significant way they reach their extreme masses.

The first direct image of a supermassive black hole's shadow and accretion disk was captured by the Event Horizon Telescope collaboration in 2019, at the center of the galaxy M87.

Intermediate-mass black holes (IMBHs)

These are a class of hypothetical or observed black holes with a mass range between 100 and 100,000 times the mass of the Sun. They are considered the "missing link" between the smaller stellar-mass black holes and the enormous supermassive black holes found at galactic centers.

They have been difficult to confirm definitively, with only a few dozen strong candidates identified so far. This difficulty stems from the fact that they are not massive enough to glow as brightly as active supermassive black holes, but they are often found in environments where detecting the motion of surrounding stars or gas is challenging. Evidence for IMBHs comes from observations of Ultra luminous X-ray Sources (ULXs) which are X-ray sources in nearby galaxies that are too luminous to be stellar-mass black holes, suggesting they may be IMBHs actively accreting matter.

Astronomers search for the gravitational influence of an unseen massive object on the motion of stars and gas in dense stellar environments, such as globular clusters. Recent analysis of stars in the globular cluster Omega Centauri provided strong evidence for an 8,200-solar-mass IMBH.

The detection of a black hole merger by LIGO in 2020 that resulted in a 142-solar-mass black hole provided evidence for IMBH formation through mergers. But, how IMBHs form is still a mystery.

Primordial Black Holes (PBHs)

Primordial black holes are a hypothetical class of black holes theorized to have formed within the first second of the universe's existence, long before stars and galaxies had a chance to form. Unlike conventional black holes that form from star collapse, PBHs would have formed from the direct collapse of extremely dense regions of matter and energy due to high-energy density fluctuations during the inflationary or radiation-dominated epochs of the early universe. They could have a vast range of masses, from smaller than an atom (though most of these would have evaporated by now due to Hawking radiation) to hundreds or thousands of times the mass of the Sun. PBHs remain purely theoretical – their existence has not yet been definitively proven. They are considered a potential candidate for a portion of the universe's mysterious dark matter.

Earliest Astrophysical Black Holes

These black holes formed slightly later in the early universe (hundreds of millions of years after the Big Bang) through conventional astrophysical processes, providing the "seeds" from which modern supermassive black holes grew.

The core collapse of the very first, massive stars (Population III stars), which were much more massive than modern stars, left behind black holes of tens to hundreds of solar masses.

In specific environments, immense clouds of primordial gas could collapse directly into black holes without first forming stars, creating heavier seeds in the range of 10,000 to 100,000 solar masses.

Observations by James Webb Telescope (JWST) have revealed surprisingly large supermassive black holes very early in cosmic history, which suggests that "heavy seed" formation or extremely rapid growth episodes were likely common.

In summary, the study of early universe black holes is critical to understanding how the massive structures we see today, particularly supermassive black holes at the center of galaxies, could have formed so quickly after the Big Bang.

An Earth-Sized Telescope

Because black holes are so distant and appear so small in the sky, a single telescope large enough to image them would need to be the size of the Earth! To

overcome this physical impossibility, the EHT collaboration used a technique called 'Very Long Baseline Interferometry (VLBI)'. They linked together a worldwide array of existing radio observatories, from the South Pole to Spain and Chile. By synchronizing the data recorded at each location using highly precise atomic clocks and combining it in supercomputers, the network effectively functions as a single, Earth-sized virtual telescope with incredible resolving power. This resolution is enough to read a newspaper in India from Europe!

Black hole Images

Black holes themselves are completely dark because no light can escape their event horizons. The images actually show the "shadow" of the black hole—a dark central region—silhouetted against the brilliant light of superheated gas swirling around it in an accretion disk. The bright, asymmetrical ring of light is emitted by plasma moving at near-light speed under the influence of extreme gravity. The immense gravity of the black hole bends the path of this light, allowing observers on Earth to see light from the far side of the black hole, which creates the distinctive ring-like structure

The EHT has released images of two supermassive black holes.
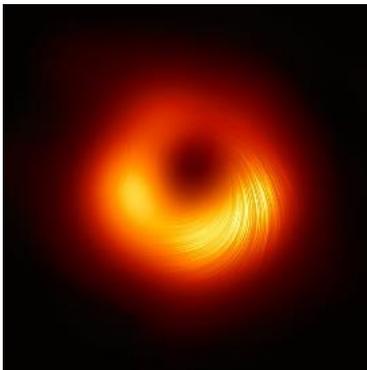
a. M87* (April 10, 2019): The first-ever image of a black hole was of the one in the center of the galaxy Messier 87, located 55 million light-years away and with a mass 6.5 billion times that of the Sun. The image confirmed the predictions of Einstein's theory of general relativity near a black hole.

b. Sagittarius A* (May 12, 2022): The EHT later released the image of the black hole at the center of our own Milky Way galaxy. Though much closer (27,000 light-years away), imaging it was more challenging because its surrounding gas orbits much faster, requiring new computational methods to account for the rapid changes during observation.

These direct images provided the first visual evidence of event horizons, revolutionizing our understanding of these mysterious cosmic objects and

allowing scientists to test the laws of physics in the most extreme environment in the universe.

Black hole at the centre of our galaxy

The black hole at the centre of the Milky Way galaxy is a supermassive black hole named Sagittarius A* (abbreviated Sgr A*, pronounced "Sagittarius A-star"). It is one of the most studied and well-understood black holes, with key characteristics confirmed by decades of observation and direct imaging It has a mass of approximately 4.3 million times that of the Sun. It is located in the direction of the constellation Sagittarius, about 26,000 light-years away from Earth. Its event horizon has a diameter of roughly 23.5 million km, which is smaller than the orbit of Mercury around the Sun. Sgr A* is relatively quiet or "dormant" compared to the active supermassive black holes (quasars) at the centres of many other galaxies. It occasionally absorbs gas or dust and experiences flares, but it is not a consistently bright, active galactic nucleus (AGN). Like all black holes, it is invisible in the optical spectrum due to both the nature of black holes themselves and a thick veil of interstellar dust and gas that lies between it and Earth.

Astronomers first detected the radio source Sagittarius A in 1974. Starting in the 1990s, two independent teams of astronomers (led by Reinhard Genzel and Andrea Ghez, who shared the 2020 Nobel Prize in Physics for their work) tracked the highly elliptical orbits of stars very close to the galactic centre, especially a star named S2. Their observations confirmed that a massive, compact, invisible object was governing the stars' motion, for which a black hole was the only explanation.

On May 12, 2022, the Event Horizon Telescope (EHT) Collaboration released the first-ever direct image of Sgr A*'s "shadow" and the glowing gas ring around it. This image provided direct visual evidence of the black hole's presence and its event horizon, matching predictions from Einstein's theory of general relativity perfectly.

Life times of Black holes

Black hole do not last forever. They have a finite, but incredibly long, lifespan determined by a quantum mechanical process called 'Hawking radiation' that was proposed by Stephen Hawking in 1974. Hawking radiation is an extremely slow process where black holes continuously emit a faint thermal radiation. This is not light escaping from inside the event horizon, but rather a quantum effect

occurring just outside it. The energy for this radiation is drawn from the black hole itself, causing it to slowly lose mass and shrink over time.

The rate of evaporation is inversely proportional to the black hole's mass.

Rotating black holes

A rotating black hole, also known as a **'Kerr black hole'** (after Roy Kerr, who solved the relevant Einstein's equations in 1963), is a black hole that possesses angular momentum and spins about its axis. Because all known stars rotate to some degree, most black holes found in nature are expected to be rotating. Kerr black holes are formed from the gravitational collapse of a massive, spinning star. A non-rotating "static" black hole is considered a mathematical idealization.Unlike a non-rotating (Schwarzschild) black hole, which has a point singularity at its centre, a rotating black hole has a ring-shaped singularity. The black hole's rotation twists the very fabric of spacetime around it, dragging objects and even light in the direction of its spin. This effect causes nearby objects to co-rotate with the black hole.

The black holes that astronomers have observed, such as the supermassive black holes in M87 and the Milky Way's centre, are all consistent with the models for rotating (Kerr) black holes. The advent of gravitational wave astronomy has provided a direct and independent way to measure black hole spins.

Black Hole Cosmology

In the extremely distant future, after all stars have died and the universe has expanded and cooled sufficiently, black holes will stop accreting matter and begin the slow process of net mass loss through Hawking radiation.

As a black hole shrinks, its temperature and radiation rate increase. In the final fraction of a second of its existence, it will lose all its remaining mass in a final, powerful burst of gamma rays and other particles.

A few theoretical models propose that our observable universe is the interior of a black hole that formed in a larger "parent" universe. In some versions of this "black hole universe" theory, matter collapsing inside the parent black hole reaches a point of extreme density, "bounces" due to quantum gravity effects (rather than collapsing into an infinite singularity), and begins a rapid expansion, creating a new, baby universe—our own.

These alternative models are not part of the mainstream, standard Big Bang theory, which describes the universe emerging from an extremely hot, dense state, but without requiring a pre-existing black hole or a "parent" universe. They

remain active areas of theoretical research, but require observational evidence to be confirmed.

References

1. Stephen Hawking: A Brief History of Time.
2. Kip Thorne: Black Holes & Time Warps: Einstein's Outrageous Legacy.
3. Edwin F. Taylor and John Archibald Wheeler: Exploring Black Holes.
4. Derek Raine and Edwin Thomas: Black Holes: An Introduction.
5. Valeri P. Frolov and Andrei Zelnikov: Introduction to Black Hole Physics.
6. Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler: Gravitation.
7. T. Padmanabhan: Gravitation.

Author

Dr. B.A. Kagali

Professor of Physics (retd.), Bangalore University, Bengaluru 560056

******

Although almost every theoretical physicist agrees with my prediction that a black hole should glow like a hot body, it would be very difficult to verify experimentally because the temperature of a macroscopic black hole is so low.

\- **Stephen Hawking**

We would look up at the night sky together, and although Stephen wasn't actually very good at detecting constellations, he would tell me about the expanding universe and the possibility of it contracting again and describe a star collapsing in on itself to form a black hole in a way that was quite easy to understand.

\- **Jane Hawking**
(First wife of the physicist Stephen Hawking)

Now, our Sun will not collapse to a black hole. It's actually not massive enough.

Janna Levin
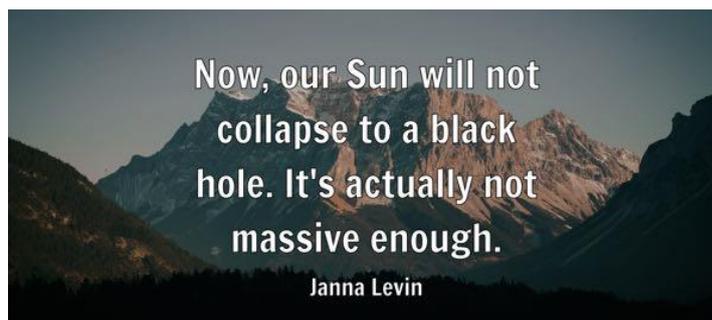
The Birth of the uncertainty Principle

In the latter part of the year 1926, Heisenberg took a job as Bohr's assistant at Niels Bohr's Institute at Copenhagen, Denmark. Then started a series of tedious but very fruitful discussions with Bohr. Bohr had his personal idiosyncrasies; he was known to engage in long long discussions. While doing so, he never bothered even if it were to be quite late at night.

Heisenberg stayed in a room in the Institute. Bohr was always too conscious about how he had been understood by the other person. Hence, he would recall the very wordings he had used in the conversation; whenever he got any apprehension in his mind that Heisenberg might have taken his analysis in a different way than what he had actually meant, he would become restless and would come back all the way to Heisenberg's room and inform him that it was a small clarification he wanted to give about what he exactly meant and then return home satisfied.

However, Heisenberg had his own way of analysis which resulted in each trying to convince the other and sometimes, it used to be frustrating for both.

On one such occasion, it became so tense that it appeared as though it would be better if both could keep separated from each other for some time. Anyhow, such a break between the two came about in a natural way at that point of time.

Bohr went to Norway in February 1927, to spend a bit of his time skiing for a few days which he normally used to do during that part of the year. Now came the opportunity for Heisenberg to concentrate in solitude about a problem (of quantum mechanics) in their discussion but keeping all the arguments of Bohr in mind.

Then he caught a point in his focus which neither of them had ever considered. That was regarding the simultaneous determination of position and momentum of a particle in a practical measurement.

Heisenberg was able to arrive at the conclusion that, despite allowing 100 percent accuracy in the instrument's ability to measure the values, nature always has a kind of *give & take balance between the inaccuracies of position and momentum values*, no matter which plan one adopts to carry out the experiment if the measurement of both is simultaneous. This restriction appears automatically in the procedure itself.

But no such problem arises if it is measurement of position alone, or momentum alone.

Heisenberg wrote a long letter to Pauli explaining his argument. Pauli not only agreed with Heisenberg but also dramatized Heisenberg's idea in his reply. Assigning the letter 'p' for momentum, and the letter 'q' for position, what he wrote to Heisenberg could be expressed somewhat like,

"You can see the world with only p-eye, and
You can see the world with only q-eye; but
if you open both the eyes at the same time,
you will go crazy".

Heisenberg sent his paper to a journal under the title,
"On the Intuitive Content of Quantum Kinematics and Mechanics".

After returning from Norway, Bohr went through the copy of the paper and suggested certain modifications to which Heisenberg resisted and wanted the paper in the same form as it had already been communicated.

That's how the famous 'Heisenberg's Uncertainty Principle' was born.

Author:
Prof. S P Basavaraju, BIT, Bengaluru

******

Karnataka to Get India's First Quantum Tech Hub!
Karnataka will host India's First commercial quantum computer at IIIT-Dharwad. A major step for India's tech future and innovation!

What actually is fire? A Physicist explains

Fire is an ancient technology that has helped shape human evolution. Our ancestors used fire for safety, cooking and preserving food. They gathered around a flickering fire to share stories, pass on cultural knowledge and build community.

Today, fire is an important industrial tool. It remains woven into our daily lives and rituals (think blowing out candles on your birthday cake). As it did millions of years ago, fire can shape our landscapes, having the power to both devastate and rejuvenate entire ecosystems.

Fire is so familiar, and yet it can be hard to define. What actually is fire?

Let's begin with a question that's a little easier to answer.

What are the ingredients for fire?

To light a fire we need three things: fuel (something to burn), oxygen and an initial spark or heat source. This is known as the fire triangle, but you could also call the fuel and oxygen "reactants" and the initial heat the "activation energy".

For a bushfire, organic matter (such as wood) provides the fuel. Oxygen is available in the air, and the activation energy could come from a range of sources, such as lightning or human activities.

If we remove one of the reactants, a fire cannot continue to burn. To extinguish a bushfire, heat can be removed by dousing the fire with water. The water is turned into steam, which also smothers the fire by displacing air. Fuel may be used up by the fire itself or be pre-emptively removed using hazard-reduction or cultural burns.

The main "product" of fire is energy, along with the gasses carbon dioxide and water vapour. When there is more fuel than there is oxygen for burning, which is the case in a bushfire, there can be additional products. One of them is soot, which is tiny half-burned particles of carbon. These products interact to provide what we feel and see when we experience fire.

The warmth we feel from a fire comes from energy as it radiates outwards in the form of heat. The hot gas products rise because they are less dense than the surrounding, cooler air. The gases carry with soot particles that glow yellow-orange because of their high temperature.

In a bushfire or campfire, it is the glowing soot that we experience as flames. Flames actually extend well above where we can see them. As the soot moves higher up, it cools and emits light in colours that we cannot see, such as infrared light.

So, what is fire?

It obviously isn't a liquid or a solid. While flames do involve hot gases, flames only exist while a fire is burning. They don't exist in a stable state on their own and we can't collect flames in a container like we could CO_2 or water vapour. Therefore, flames and fire are not gases.

We can also rule out plasma – the fourth state of matter. Plasma is similar to an extremely hot gas but with some key differences.

A plasma contains so much heat energy that atoms in the plasma become ionised, meaning they can no longer hold on to all of their electrons. The plasma is like a soup of charged particles, both electrons and ionised atoms, which can conduct electricity and respond to a magnetic field.

In the hottest parts of the most intense fires, it is possible that there are enough ionised atoms to form areas of weak plasma. However, the plasma is not stable on its own and fire, as a whole, does not behave like a plasma.

In fact, fire is not matter at all. Fire is a process. It is a type of chemical reaction called combustion.

A process unique to Earth

Gasses and plasma are everywhere in the universe, but fire as we experience it – with visible, oxygen-fuelled flames – appears to be unique to Earth.

The Earth itself formed from dust and gas around a young Sun, which is so hot that it is almost entirely plasma. The universe is home to trillions of galaxies, each filled with stars and possible planetary systems, so there's a lot of gas and plasma out there.

Meanwhile, our Earth is the only place in the universe where fire is known to be possible.

That's because one of the key ingredients for fire – a stable supply of oxygen – is a by-product of life. And as far as we know, life only exists here on Earth.

Author:
Jo Adetunji, Editor, The Conversation, UK

******

Sir Chandrasekhara Venkataraman (Sir C V Raman) was a brilliant Indian Physicist known for his work in the field of lights scattering. The light scattering named after him, earned him Nobel prize in 1930. He was the first Asian Scientist to be awarded Nobel Prize. Every year 28th February (Raman Effect was discovered on 28th February 1928) is being celebrated as National Science Day in our country to commemorate the discovery of Raman Effect.

Brilliant student, he was: Raman passed his matriculation at 11, F A (present PUC) at 13, BA at 15, M A at 18, civil services examination and joined Finance Department as Assistant Accountant General at 18 ½ years.

Thin Unimpressive Boy: When he was in studying in Presidency College, Madras, physically he was a thin unimpressive boy with a dothi draped in the South Indian (cylindrical style) style, a cap and no foot wear. A story goes like this. One of the professors could not believe that this diminutive boy was a student of the Presidency College. The Professor asked Raman whether he had come to the class by mistake and caused laughter in the class.

In a short span of time, his teachers found him remarkably brilliant and found that he knew most of the stuff taught in the class and he had nothing to learn from them. Hence, he was exempted from attending all the science classes. As a student, he published two papers in The Philosophical Magazine: one on Diffraction bands and the other on New Experimental Method of Measuring Surface Tension.

First Occasion: Though Raman hailed from orthodox family, against all conventions that prevailed at that time, he arranged his own marriage with Ms Lokasundari. He married her when she was thirteen. There is a story that when Raman saw Ms Lokasundari for the first time, she was playing on the veena the Saint Thyagaraja's composition "Rama Nee Samanamevaru". Was it coincidental or intentional, we will never know.

Man of Supreme Self-Confidence: Raman was awarded the Nobel Prize for his wok named after him (Raman effect) in 1930. Earlier, in 1924, Raman was elected a Fellow of the Royal Society of London. At a felicitation function, when he was asked by Mr Asuthosh Mookerjee, then Vice Chancellor of Calcutta University as to what was his next goal, he seemed to have said that he would get Nobel Prize for India within five years. He was awarded Nobel Prize in 1930.

Nobel Prizes are announced in the month of October/November every year. Prize distribution ceremony is held in mid-December at Stockholm, Sweden. Surprisingly, Raman had booked two tickets for himself and his wife in July that year so that they could leave by steamship to reach Stockholm well in time for the prize awarding ceremony.

Raman enjoyed doing science. The joy of doing science filled him with enthusiasm and excitement.
(Source: A Pictorial Biography Published by The Indian Academy of Sciences.)

Wolfgang Ernst Pauli was a famous Austrian theoretical physicist who received Nobel Prize in 1945 for the discovery of the Exclusion Principle. He was nominated for the Nobel Prize by none other than Albert Einstein. He is remembered for

1. Pauli's Exclusion Principle

2. Pauli's Neutrino Hypothesis

3. Legendary Effect called "Pauli's Effect".

While the first two refer to his outstanding scientific discoveries, the third one refers to the legendary effect where laboratory equipments mysteriously malfunctioned in his presence. Experimental apparatus would suddenly break when Pauli entered a laboratory; a cyclotron caught fire at Princeton university in 1950 in his presence and a telescope in an observatory was damaged. Otto Stern seriously wanted to deny Wolfgang Pauli access to his institute for fear of such unwanted mishaps.

Pauli himself was aware of this strange "gift" that he had inherited and thoroughly enjoyed these humorous incidents. There is a humorous saying which reads like this: When Pauli entered a room an experiment would fail, when a theorist Weisskopf entered it would succeed.

Continuing with Pauli's infamous tendency to cause equipment failure, his new car failed during a honeymoon without apparent reason. Interestingly in a reception party, his friends wanted to parody the Pauli effect by deliberately dropping a chandelier upon Pauli's entry. But to everyone's astonishment, the chandelier got stuck to a chain thus becoming another example for demonstrating Pauli's effect.

Pauli was personally disgusted with this strange gift. It is said that he wanted to become an experimentalist. But his tendency to cause equipment failure made him change his decision and become a celebrated theoretical physicist.

Pauli was fascinated by the number 137, related to fine structure constant. Ironically, he died in room 137.

Richard Phillips Feynman was an American theoretical physicist. He is best known for theory of Quantum Electrodynamics, the Physics of the Superfluidity of supercooled Liquid helium, and in particle physics, for which he proposed the parton model. For his contributions to the development of quantum electrodynamics, Feynman received the Nobel Prize in Physics in 1965 jointly with Julian Schwinger and Shin'ichirō Tomonaga.

Feynman was a keen populariser of physics through both books and lectures.

As a young boy, Feynman demonstrated extra ordinary level of curiosity. On one occasion, he was amused with rolling of a ball in a truck. The story goes like this.

Little Richard: Dad, I noticed something: When I pull the wagon the ball rolls to the back of the wagon, and when I'm pulling it along and I suddenly stop, the ball rolls to the front of the wagon. why is that?

Richard's Dad: That nobody knows… The general principle is that things that are moving try to keep on moving and things that are standing still tend to stand still unless you push on them hard. This is called inertia. But, nobody knows why it is true.

In the Manhattan project at Los Almos, Niels Bohr, a great physicist was going to present a new calculation. Bohr knew well that no one other than Feynman would have the audacity and courage to challenge or question his work, because Feynman always spoke his mind and he was straight forward.

On the previous night, Bohr sent his son Aage Bohr to call Feynman. Bohr showed Feynman his calculations. Feynman was genuinely astonished as when there were so many great scientists in the project why Bohr had picked him up. But then gradually became serious and he got lost in the calculations.

At one point while looking closely at the calculations he seemed to have said, "What is this Sir? There are 7 unknowns and just 6 equations. How can you solve it? Are you nuts?"

Someone calling world famous Nobel prize winner physicist father as nuts, Aage Bohr could not digest the humiliation and became bit aggressive but Neils Bohr knew Feynman's nature and he stopped his son from reacting. He wrote down the Schrodinger's equation on the board. Feynman looked at the board and said, "Now let's solve it."

Three hours later, the board and another 3 boards near to it were completely filled with mathematical equations. Feynman congratulated Niels Bohr and left his home at 3am in morning.

Aage Bohr, on instructions from his father, accompanied Feynman to see him off. Feynman asked Aage Bohr, "Why did your father pick me from all other geniuses here in the project?"

Aage Bohr said "because none of the geniuses can call my father as NUTS".

Feynman "You mean I will call Dr. Bohr as nuts?? Are YOU nuts??"

Ernest Rutherford, the Father of Nuclear Physics, is known for developing nuclear atom model. Based on experiments with Alpha Ray Scattering by atoms, he proposed the nuclear atom model which was experimentally confirmed by Geiger and Marsden. Rutherford's intuition to a new planetary model of the atom in which electrons orbit round the nucleus is regarded as one of the most outstanding insights of the 20th century modern physics.

It is often remarked that Rutherford looked inside the atom. He was awarded Nobel Prize in Chemistry in 1908.

Counting Thunder: Even as young boy, Rutherford demonstrated remarkable scientific curiosity. He was found in a thunderstorm counting seconds (measuring time) between lightning and thunder to gauge the distance.

Tissue Paper Analogy: Very famously, while describing the atomic structure after few alpha particles bounced back on hitting the target, he seemed to have remarked that it was like firing 15" shell at a tissue paper and having it come back.

First to Coin the terms Alpha and Beta: Rutherford was the first to coin the terms Alpha and Beta while describing the two types of radiation emitted from radioactive sources uranium and thorium. He noticed that distinctly two types of particles appeared to be emitted from radioactive sources. The first one was absorbed by a few thousands of a centimeter of the foil, while the second one could pass through 100 times, or so, as much foil before getting absorbed.

Later, he discovered a third kind, that he duly called "Gamma".

Petrolhead in his spare time: Rutherford had an extraordinary love for cars and golf in his spare time. He strongly believed in the saying "Work hard, Play hard". He bought his first car in 1910. He wrote to his mother describing his driving experience "It is very desirable to have some means of getting fresh air rapidly."

I quote Rutherford. "All physics is either impossible or trivial. It is impossible until you understand it, and then it becomes trivial"

Wilhelm Conrad Roentgen was a German experimental physicist who discovered X rays. For his groundbreaking invention, he was awarded the first-ever Nobel Prize in Physics in 1901 thus he became the first recipient of Nobel Prize in Physics. He donated the entire prize money to his university. Generosity of the man was appreciated by everyone.

Accidental Discovery: On November 8th 1895, Roentgen was working in his laboratory at University of Wurzburg, experimenting with cathode ray tube. He had covered it with a heavy black paper to avoid any light. To his astonishment, a screen coated with a fluorescent material (barium platinocyanide) and kept several feet away from the apparatus in the dark room started to glow. He thought that it must be some new unknown type of radiation emitted from the tube which passed through the opaque paper and caused the glow. He aptly called them X rays, meaning unknown rays.

Roentgen must have gone mad: Roentgen was meticulously and devotedly engaged in his research. He was very cautious about his observation that he did not want others to know what he was doing. Several times, his wife Anna Bertha Ludwig insisted on knowing what he was doing in the lab. All he would say was that if people come to know, "they would say Roentgen must have gone mad."

The First Roentgenogram: After carrying out experiments for several weeks with total dedication and commitment, Roentgen made public first medical image of his wife's hand on 22nd December 1895. The image clearly showed the bones and wedding ring of Ms Anna Bertha Ludwig. On seeing ghostly image of her hand with bones, Anna seemed to have remarked "I have seen my death."

Refusal to Patent: This incident is being mentioned here to recognise and appreciate the societal concern of Prof. Roentgen. Roentgen refused to take patent for his outstanding discovery. Because, he wanted society as a whole to benefit from the medical and other practical applications of X rays.

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

Author:

Dr B S Srikanta
Former Director and Principal, Sindhi College, Surana College

Aurora

An aurora is a natural light display in the sky, caused by energetic charged particles from the Sun colliding with gases in Earth's atmosphere, creating vibrant colors (green, pink, red, blue) often seen near the poles as the Northern Lights (Aurora Borealis) or Southern Lights (Aurora Australis). Due to the ionisation of gaseas molecules, considerable number of atoms and molecules are elevated to excited states. When they make the transition back to their ground states they emit light characteristic of the atoms and molecules.

When energetic charged particles enter the earth's atmosphere from the solar wind, they tend to be channeled toward the poles by the magnetic force which causes them to spiral around the magnetic field lines of the earth. It does offer an impression of how the magnetic field of the Earth helps to protect us from the ionizing radiation of particles from the solar wind.
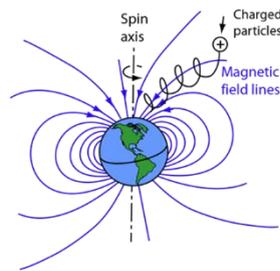

Fig1 : Conceptual sketch of charged particles spiraling around magnetic field lines.

Earth Aurora Australis:

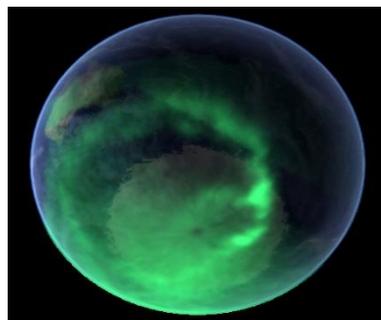A polar satellite captured the following image of Earth Aurora Australis.

Fig2: NASA image of aurora australis taken by Polar satellite, November 2004

The Sun produced at least five major "halo" coronal mass ejections (CMEs) over the period of Nov. 4–8, 2004, an unusually fast pace for solar activity. The Polar spacecraft saw the aurora australis expanding and brightening on Nov. 8. A "halo" CME occurs when a CME produces an expanding circle of particles all around the Sun. The observers seen all were heading in our direction, bringing the auroral light formation.
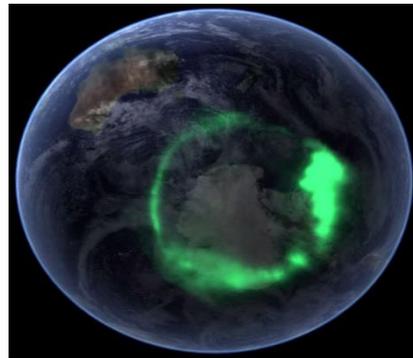

Fig3: NASA image of aurora australis taken by IMAGE satellite, September 11, 2005

From space, the aurora is a crown of light that circles each of Earth's poles. The Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) satellite captured this view of the aurora australis on September 11, 2005, four days after a record-setting solar flare sent plasma—an ionized gas of protons and electrons—flying towards the Earth.

The ring of light that the solar storm generated over Antarctica glows green in the UV part of the spectrum, shown in the above image. From the Earth's surface, the ring would appear as a curtain of light shimmering across the night sky.

Though scientists knew that the aurora were caused by charged particles from the Sun and their interaction with the Earth's magnetic field, they had no way to measure the interaction until NASA launched the IMAGE satellite in 2000. The satellite's mission was to collect data that would allow scientists to study the structure and dynamics of the Earth's magnetic field for the first time.

Designed to operate for two years, IMAGE sent its last data to Earth in December 2005 after a highly successful five-year mission. Since 2000, IMAGE has provided insight into how the Earth's powerful magnetic field protects the planet from solar winds. Without the magnetic field shield, the upper atmosphere would evaporate into space under the influence of solar winds.

IMAGE has shown scientists what sort of changes the magnetic field undertakes as it diverts solar winds from the Earth.

Jupiter Aurora:

UV photograph of Jupiter indicates that auroral phenomena occur in its polar regions.

Fig4: NASA image of Jupiter's aurora taken by Hubble Space Telescope's STIS, November 26, 1998

Like the aurora near the Earth's poles, the glowing display near Jupiter's poles comes from the interaction of charged particles with the planet's magnetic field, which is more intense near the poles.

Jupiter's aurora show the distinct magnetic footprints of three of Jupiter's larger moons: Io, Europa and Ganymede. The luminous path at extreme left is from Io and the one near the center from Ganymede. The path below and to the right of Ganymede's trail is from Europa.

The strong electrical and magnetic interactions of these moons with Jupiter has been a subject of intense study.

Saturn Aurora:

Images of Saturn aurora show a very active pulsating pattern.

Fig5: UV image of Saturn aurora at southern polar region was taken by Hubble Space Telescope's Imaging Spectrograph, January 28, 2004

The visible part of the image was taken by Erich Karkoschka of the University of Arizona using the telescope's Advanced Camera for Surveys on March 22, 2004. The UV image was transferred to the visible blue to show the geometry of the auroral display and superimposed upon the subsequently obtained visible image.
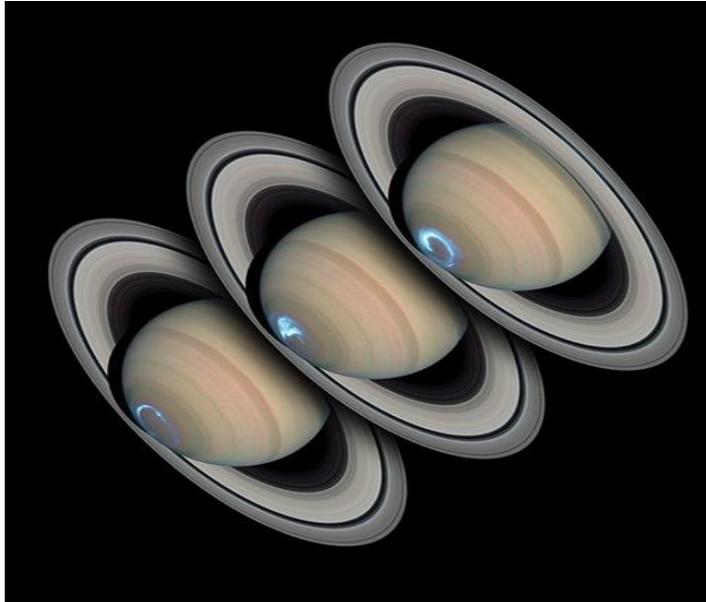

Fig6: UV parts of the three superimposed images of Saturn aurora at southern polar region taken on January 24, 26, and 28, 2004.

This shows the dynamic nature of the auroral display. On Earth, auroral storms may develop in about 10 minutes and last for a few hours, whereas Saturn's auroral displays always appear bright and may last for several days.

The observations, made by Hubble and the Cassini spacecraft while enroute to the planet, suggest that Saturn's auroral storms are driven mainly by the pressure of the solar wind, a stream of charged particles from the Sun, rather than by the Sun's magnetic field.

The aurora's strong brightening on Jan. 28, 2004 corresponds with the recent arrival of a large disturbance in the solar wind. The image shows that when Saturn's auroras become brighter and thus more powerful, the ring of light encircling the pole shrinks in diameter.

Author:
Dr. Rudraswamy B.
Professor (retired), Dept. of Physics, Bangalore University

******

Skills can become obsolete: Why Nobel prize winner Ester Duflo wants students stop chasing 'perfect' careers

At a time when students are constantly told to be "job-ready", Nobel Prize–winning economist Esther Duflo offered a very different — and quietly powerful — message. Speaking at the 19th Jaipur Literature Festival, she reminded young people that the skills they are racing to acquire today may not be the ones that shape their careers tomorrow, reports PTI.

"The entire landscape is evolving so fast that the specific skill you are teaching someone will become obsolete by the time they finish their education, and certainly by the time they enter the job market," Duflo said during her session at the festival.

Her point was not meant to discourage students, but to free them from a narrow idea of success that equates education with immediate employability.

The problem with skill-chasing

Most learners these days program their schooling to comply with the present requirements of the job market. Programming languages, instruments, certificates, and focused training usually seem like the surest way to a stable life. Duflo cautioned that this feeling of being secure might deceive them.

With technology — especially artificial intelligence — changing how work is done, job roles are being reshaped faster than ever. A skill that looks essential today could become outdated in a few years, sometimes even before students graduate.

When education focuses too narrowly on such skills, students risk being prepared for jobs that no longer exist.

College is meant for the long run

Duflo urged students to think of college not as a shortcut to employment, but as preparation for a lifetime of decisions, changes, and learning. The real value of higher education, she argued, lies in building abilities that last.

"College education needs to involve a strong humanities background: the ability to write, the ability to think, and the ability to make decisions for yourself," she said while speaking at the Jaipur Literature Festival.

These include learning how to think clearly, write well, question ideas, and make reasoned judgments. Such skills do not appear on most job descriptions, but they are what help people grow, adapt, and stay relevant across decades-long careers.

Why the humanities still matter

In a time when the whole world is running after technical and professional degrees, Duflo has brilliantly defended the value of humanities. Duflo emphasized that study of humanities such as philosophy, history, ethics, and social sciences should be at the core of students' education.

These help students develop an understanding of the world, and not merely being able to get by in it. Even students who are techie and data-focused, these subjects are still helpful in developing insight, judgment and a sense of responsibility.

She argued that, whereas any task can be done by machines, only humans, through their values, ethical thoughts, and broad vision are still irreplaceable.

Learn the basics, not just the tools

Another key message from Duflo was the importance of fundamentals. Learning how to use a tool is helpful, but understanding the ideas behind it — logic, mathematics, reasoning — is what gives knowledge staying power.

"Rather than learning to write lines of code, you need to learn fundamental probability and statistics because this is what is under the hood of these things that are going to help you moving forward," Duflo explained at the Jaipur Literature Festival.

Tools will change. Technologies will evolve. But students who understand the basics will always be able to adapt, no matter what the next shift looks like.

A reality check for Indian students

For Indian students, often under pressure to choose "safe" degrees with clear placement outcomes, Duflo's words feel especially relevant. An education system focused only on exams and short-term results can leave graduates struggling when careers take unexpected turns.

"In some sense, and at some level, the way technology is moving forward means that we need to move backward — or perhaps move higher up — to rethink the fundamentals of what education is," she said, as quoted by PTI, reflecting on how education systems need to respond to change.

What students really need, she implied, is confidence in their ability to learn again and again — not fear of stepping outside a fixed career path.

The takeaway

Esther Duflo is not arguing against skills or careers. She is asking students to look beyond the immediate promise of a job and think about who they want to become over time.

In a world where careers will change many times, the most valuable education is one that teaches you how to think, adapt, and keep learning. For students planning their futures today, that may be the most reassuring lesson of all.

Source: TOI Education, with inputs from PTI.

******
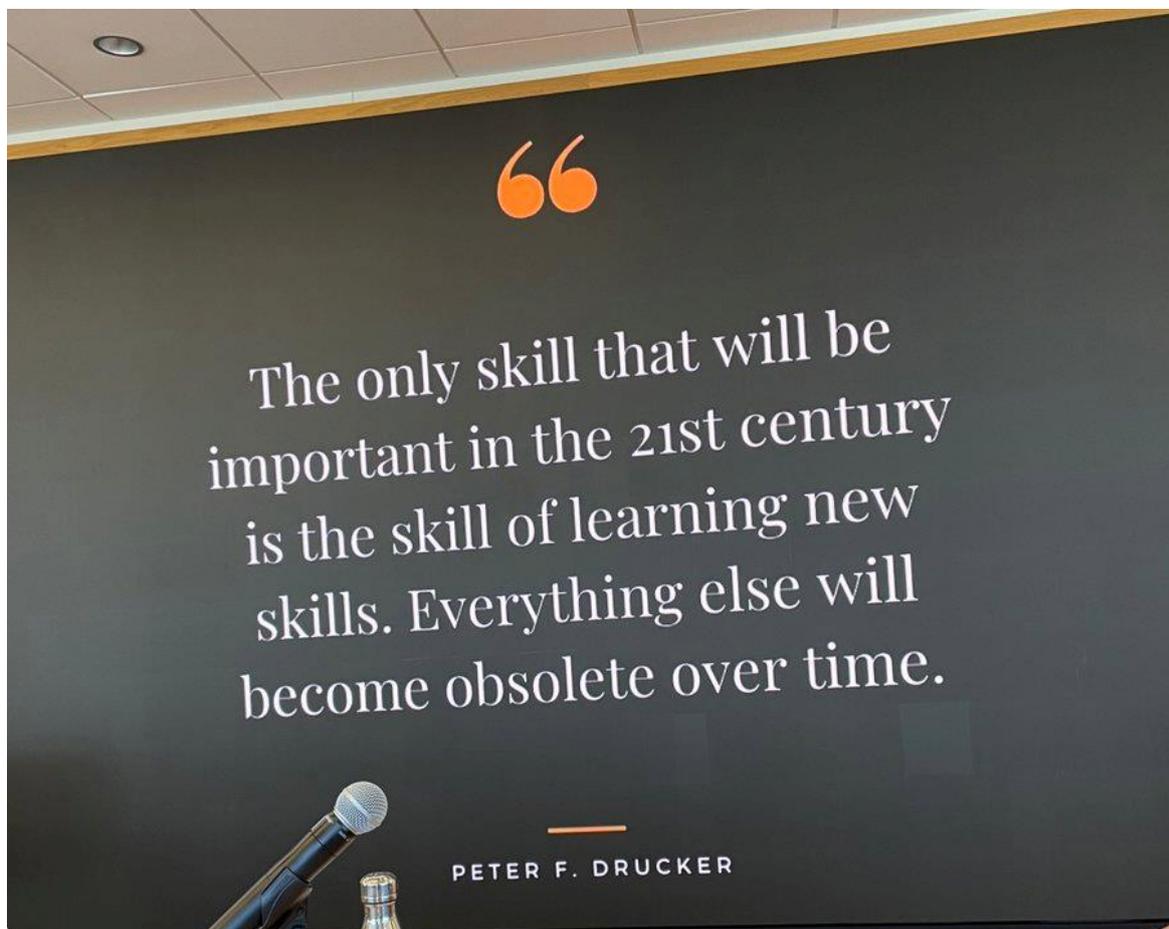
The Incredible Brian May

In 1970, a 23-year-old physics student at Imperial College London found himself at a crossroads most people will never face.

Brian May had spent three years studying cosmic dust — specifically, the zodiacal light, that faint glow created by sunlight reflecting off tiny particles scattered through the solar system.

He'd built instruments, collected data, analyzed measurements. His PhD in astrophysics was within reach.

But he was also the guitarist for a band that had just landed a record deal.

A band called Queen

Tours were booked. Studio time was scheduled. Momentum was building. If he stepped away for a few months to finish his thesis, the opportunity might disappear forever.

So Brian May made the choice that would leave his doctorate unfinished for 36 years. He chose the guitar.

What followed was one of the greatest careers in music history.

Queen skyrocketed.
"Bohemian Rhapsody" exploded into the culture. Stadiums thundered with "We Will Rock You" and "We Are the Champions."

Brian's homemade guitar — the Red Special, built from fireplace wood, motorcycle springs, and his father's engineering brilliance — became a signature part of rock's soundscape.

His PhD gathered dust. His scientific career went dormant. But his curiosity never faded.

Most people would've left the abandoned doctorate behind.

Brian May couldn't.

Throughout the '70s and '80s, even at the height of Queen's fame, he remained tethered to the world of science.

He read journals. Attended lectures on tour breaks. Followed astrophysics like old friends follow sports scores.

And he never forgot what his thesis advisor, Michael Rowan-Robinson, once told him:

"You can always come back and finish."

In 2006 — three and a half decades after leaving academia — Brian May walked back through the doors of Imperial College.

Rowan-Robinson was still there. He still remembered his former student who'd vanished into rock stardom. And he was willing to help him finish what he'd started.

The challenge was enormous.

Astrophysics had transformed since the 1970s. Instruments, models, and calculations had all advanced. May's original data was valuable but outdated.

To finish the thesis, he couldn't simply dust off old notes — he had to update his work using modern research, new discoveries, and current scientific standards.

So he did.

Between tours with Queen + Paul Rodgers, between shows and studio sessions, Brian May returned to the equations, the data, the problem he'd left behind at age 23: the velocities of dust particles drifting through the inner solar system.

He rewrote, recalculated, reanalyzed.

In 2007, Imperial College awarded Brian May a PhD in astrophysics for his thesis, *A Survey of Radial Velocities in the Zodiacal Dust Cloud*.

Not honorary.
Not symbolic.
A real PhD, earned under full academic scrutiny.

At age 60, one of rock's greatest guitarists became Dr. Brian May — astrophysicist.

It made news not because a celebrity received a diploma, but because the story defied expectation.

The world loves to sort people into labels: artist or scientist, logical or creative, rock star or academic. Brian May proved you can be both.

You can build a guitar from fireplace scraps, electrify millions of fans, and still devote yourself to the physics of cosmic dust.

After earning his doctorate, he didn't frame it and move on — he used it.

He became Chancellor of Liverpool John Moores University. Co-founded Asteroid Day to raise awareness about planetary defense. Worked with NASA on stereo imaging from the New Horizons mission to Pluto, published books blending astronomy with 3D photography. Lectured around the world.

And, of course, kept playing music.

He didn't return to science to redeem himself or impress anyone. He returned because unfinished work matters. Because curiosity endures.

Because the desire to understand the universe doesn't expire with age or fame.

His journey speaks to anyone who ever had to pause a dream — for work, for family, for opportunity, for life.

It proves that longer roads can still lead to meaningful destinations.

That you can step away without abandoning who you are. That passion can wait decades and still be fulfilled.

Brian May's story isn't about choosing between art and science. It's about refusing to choose. It's about understanding that human beings are capable of living in multiple worlds at once.

The kid who built a guitar with his dad?
He never stopped being the kid who loved the stars.

Some people shred solos in front of 80,000 fans. Some people study cosmic dust. Brian May did both.

And sometimes, the homework you put off for 36 years is the one most worth finishing.

Author:
Prof. Ramaswamy Balakrishnan
Professor of Physics (retd.)

******

ICPE – 2025 (December 16–20, 2025): IIT ROPAR, Rupnagar

My Experience

ICPE – International Conference on Physics Education, is a flagship conference of International Commission on Physics Education ICPE – C 14 of IUPAP (International Union of Pure and Applied Physics).

Theme: Physics Education; Preparing for the future in the age of virtual labs, AI and quantum technologies.

IIT Ropar was the host Institution, IISER Mohali and IAPT were the Co-hosts.

ICPE – as an international gathering of Physics Educators, Physics Education researchers, Physics Teachers and Students at all levels. As a leading STEM discipline, Physics has excelled globally in research pertaining to subject specific education.

Themes and broad themes of the Conference

1 Advancement in Physics Education research

• STEM and Physics Education synergies and challenges
• Impact on large scale policy on Physics Education
• Undergraduate and Post graduate Physics
• Physics Teacher Education
• Designing Physics Curriculum and assessment; Schools, Colleges, Universities

2 Women in Physics

• Role of women in Physics teaching and learning in Schools, Colleges and Universities

3 Physics – enabled virtual adaptability in Education

• Hands-on Real-time laboratories, virtual labs, labs to simulation
• Tutorial and recitation sessions
• Flipped teaching and learning

4 Quantum technologies and Physics Education

• Celebrating the International year of quantum science and technologies
• AI in Physics Education
• Workforce creation

5 Physics outreach

• Access to Physics Education for the majority and minority reaching the unreached
• Physics out reach and in media
• Physics for Climate change

Thus ICPE 2025 focuses on a wide range of themes including the integration of AI in Physics teaching and quantum-based learning.

A number of International participants attended and took part actively in the conference.

The delegates from leading Institutions such as the University of Sydney, University of Washington, University of Pittsburgh, Kansas State University, Ohio State University, University of Oregon, Chiang Mai University, University Ljubljana, Uppsala University of Udine and CERN.

Prominent international speakers include Prof Paula Heron (University of Washington), Prof Chandralekha Singh (University of Pittsburgh), Prof Dean Zollman (Kansas State University) and Prof Marisa Michilini (University of Udine), Prof Geraldine L Cochran (Ohio State University), Faletic, Sergej, University of Ljubljana, Slovenia, Prof Manjula Sharma (University of Sydney).

Structure of the Conference

Sunil K Gupta, President IUPAP – Key note Address: The IUPAP and its role in Global Physics Education and Sustainable development.

Ajay Kumar Sood – Chief Guest Address: Journey from curiosity driven Physics to mission driven Science policy – Vigyan Kartavya to Kartavya Bhavan.

PT (Plenary Talk – 30+2 mins) – 4 talks

1. Prof Manjula Sharma, Chair, IUPAP Commissioner of Education, University of Sydney
   Confluence of Social drivers and education research on Physics education: Implications in the age of AI

2. Prof Arun Kumar Grover – Former Vice Chancellor of Punjab University
   The initiation of Teaching of Science and the spread of research in Physics in India since CIRA 1850 – A comprehension

3. Prof Chandralekha Singh, Distinguished Professor of Physics, Pittsburgh University
   Helping students become leaders of the second quantum revolution

4. Prof Dean Zollman, Distinguished Professor, Kansas State University
   Transfer of learning applied to student use of AI

MT (Medal talk – 25+2 mins) – 2 talks
1. Prof Pornrat Wattanakasiwich – Chiang Mai University, Thailand
   Developing an ethics–aware Chatbot to support Physics students research writing

2. Prof David Sokoloff – University of Oregon, USA
   Making Physics learning around the Globe more active

IT (Invited talk – 20+2 mins) – 26
OP (Oral presentation – 8+2 mins) – 38
PP (Poster Presentation – displayed for 3 days) – 53 (23 from IIT ROPAR Ph.D. Scholars)

Open workshops – 10

W (Workshop – 1 hr 20 mins) – 11

1. Vandana Luthra (Delhi) – Contemplating Quantum Foundation and applications through Qiskit

2. Y K Vijay (Jaipur) – Hands on Workshop on innovations in Science teaching – Demonstration of lattice potential and Fermi surfaces and Bohr's Quantization

3. Pragya Nopany (Anveshika – Delhi) – "Physics Pe Charcha" through engaging demonstration for Active Learning

4. Uthra Dorairaju (Tamil Nadu) – Hands on Training program for School teachers on the design and use of Teaching / Learning Aids in classrooms

5. OSKS Sasthri (Dharamshala) – Computational simulation in Quantum Physics

6. Jithin Bhagavathi (Spark Research) – Hands on Physics with affordable open–source measurement tools: From theory to experiment with Seelab 3

7. Jay Thakkar & Imronz Khan (IIT Gandhinagar) – Joyful Physics with simple toys

8. Ankish Tirpude (IISE Pune) – Engaging with induced EMF using low cost visualization

9. Dev Dutt (Himachal Pradesh) – Development of low-cost physics experiments from School to University to support experiential learning

10. Sapna Sharma (Shimla) – Quantum Mechanics in the world of virtual simulated resources

11. Ananthnag and Purushotham – Agastya International Foundation, Kuppam – Make your own lab: low cost Educational Resources for Science teaching learning

Day 1: 16.12.2025 (Tuesday)
The Inaugural session was graced by Prof Ajay Kumar Sood, Principal Scientific Adviser to the Government of India, National Science Chair, and Professor of Physics at IISc, as the Chief Guest.

Addressing the gathering, Prof Sood underlined the pivotal role of Physics education in strengthening India's scientific ecosystem and driving innovation. He emphasized the need for modern pedagogical approaches, particularly in areas such as AI, quantum science and virtual laboratories, to prepare students for future scientific challenges.

He said that Physics is the language of nature, deals from the smallest particle to largest structure, Micro–Macro. He mentioned Climate models, MRI, PET scanner, optical sensors, semiconductors, nanomaterials, Higgs Boson, superposition, entanglement, systematic thinking, analytic reasoning, critical evaluation, quantitative problem solving, conceptual clarity, Raman scattering.

Prof Manjula Sharma, Chair, IUPAP Commission of Education C–14, Professor of Science Education and Director of the STEM Teacher Enrichment Academy, spoke on the development of Physics measurements, confluence of social drivers and education research on physics education and implications in the age of AI. She said India joined IUPAP in 1948.

Prof David R Sokoloff, Professor Emeritus, University of Oregon USA and former President, American Association of Physics Teachers, was awarded IUPAP 2024 medal virtually, and Prof Pornrat Wattanakasiwich, Chiang Mai University, Thailand, was awarded IUPAP 2023 medal.

Prof Anil Kumar Tripathi, Director IISER Mohali, mentioned that they had trained Astronomy Olympiad students in 2004 and five Gold Medals were awarded.

Prof Mukesh Kumar, Acting HOD Physics, IIT Ropar, said that the Department of Physics is undertaking research in various fields including Quantum Optics and Nonlinear Phenomena.

Prof Arun Kumar Grover, former Vice Chancellor of Punjab University, Prof Sudarshan Iyengar, HOD CSE IIT Ropar, and Prof P K Ahluwalia, President IAPT, were on the stage and also spoke.

Prof Arvind, Co-Chair of the Conference, welcomed the gathering and proposed the vote of thanks.

In the afternoon, Prof Paula Heron, University of Washington, chaired the session.

Prof Pornrat Wattanakasiwich (Medal Talk) spoke about developing an AI ethics–aware chatbot to support physics students' research writing and discussed epistemological automation, augmentation, inclusion and innovation.

Prof Bhas Bapat, IISER Pune, mentioned that undergraduate teaching needs a different look at experiments and that laboratory sessions should be given more importance than theory.

Parallel sessions followed, with workshops in two small auditoriums and invited talks in two others from 2.30 pm to 4.00 pm.

From 4.00 pm to 5.30 pm, poster presentations and open workshops were conducted.

P Nagaraju presented a poster on "A revisit to Ferroelectric to Paraelectric".

M S Jogad presented a poster on Quantum materials, quantum computer technology and communication.

The keynote address was presented by Prof Sunil Gupta, President IUPAP, TIFR Mumbai, on the role of IUPAP in global physics education and sustainable development.

Day 2: 17.12.2025 (Wednesday)

There was a virtual medal talk by Prof David Sokoloff on Force and Motion using live classroom examples.

Prof Paula Heron spoke about evolving relationships among theory, experiment and teaching practice in Physics Education Research.

Anveshika groups demonstrated experiments including torque, inertia, conservation of angular momentum, sound, and properties of materials using liquid nitrogen.

Parallel sessions of invited talks and oral presentations followed.

Day 3: 18.12.2025 (Thursday)

Prof Chandralekha Singh spoke on the quantum revolution, QUILTS, quantum information sciences and early career exposure.

Prof Dean Zollman discussed AI's potential to transform higher education.

Prof Arnab Bhattacharya spoke on bringing semiconductor materials into classrooms through low-cost experiments.

Parallel oral presentations and workshops followed, along with a cultural programme in the evening.

Day 4: 19.12.2025 (Friday)

Parallel workshops on computational physics were conducted.

A panel discussion on Physics and Industry emphasized industry-oriented curriculum and internships.

P Nagaraju presented a paper on "Superposition of electrons in the presence of electromagnetic field".

M S Jogad presented a paper on low-cost experiments and awareness of quantum science.

Day 5: 20.12.2025 (Saturday)

Prof Geraldine L Cochran spoke on quantitative literacy in physics.
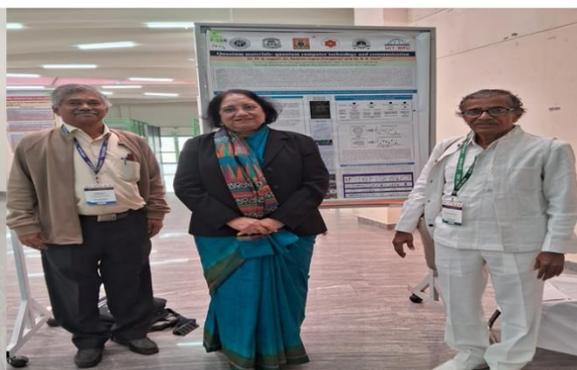
Prof Arvind spoke on learning and teaching physics through experiments.

The conference concluded with a vote of thanks.

Author:

P Nagaraju

Former Faculty, Vijaya College & The National College, Bengaluru

******

The Candle That Spoke Softly

A candle burns quietly.

Wax melts, vaporizes, reacts with oxygen, and disappears into air and light. Nothing dramatic happens. No conch is blown, no curtain rises. If this were a scene in an epic, the audience might assume it is merely background activity — something to be ignored while waiting for the real action. Yet in this quiet, almost apologetic act, one of the deepest principles of physics is being enacted with perfect obedience: a small portion of the system's rest energy is released and reappears as heat, light, and motion — or, in the compact and infuriating shorthand of popular speech (and to the lasting annoyance of David Griffiths), "mass turns into energy." Physics says this without excitement:

$$E = mc^2$$

The candle obeys it. The nucleus obeys it. The universe does not ask whether we are suitably astonished. **We, human beings, however, have always preferred astonishment to understanding.**

Small Truths and the Fate of Vidura

Scientifically, the candle is beyond suspicion. The mass before burning exceeds the mass after burning by exactly the amount predicted by relativity. This is not speculation. It is arithmetic. Yet we do not treat it as revelation.

The candle's situation is uncannily similar to Vidura's in the Mahabharata. Vidura spoke nothing but truth, sound policy, and moral clarity — quietly, consistently, without spectacle. He was correct almost always. His counsel was impeccable — and largely ignored. He was correct with remarkable consistency, and ignored with equal regularity. His advice, in short, suffered from an unfortunate shortage of listeners. Duryodhana did not reject Vidura because Vidura was wrong. He rejected him because Vidura was calm. **The candle suffers the same fate**.

When Bhima Speaks, Everyone Listens

Nuclear fission, on the other hand, does not speak like Vidura. It speaks like Bhima. It does not reason gently; it announces itself with force. It does not invite contemplation; it compels attention. When mass–energy equivalence appears in nuclear reactions, the effect is so large that denial becomes impractical. And so

we nod and say, "Now it is proven," as if the candle had not been saying the same thing all along — only without a mace in hand.

Mark Twain would have enjoyed this moment. He had little patience for ignorance, but even less for misplaced confidence. What gets us into trouble is not always what we do not know, but what we are cock-sure of without ever having had a good reason.

For centuries, we *knew* mass was conserved. The candle disagreed softly. The nucleus disagreed loudly. **We believed the louder one**.

The Curse of Small Numbers

The macroscopic candle releases energy through small events in the electronvolt scale. The microscopic nucleus releases energy in mega-electronvolts. This difference in scale has achieved something remarkable: it has convinced us that the principle itself changes with magnitude. This is like refusing to believe gravity exists because apples fall quietly, but conceding its existence only after witnessing a landslide.

In the *Ramayana*, Ravana listens patiently to Mandodari and Vibhishana — and does nothing. Wisdom that arrives quietly is dismissed as opinion; wisdom that arrives catastrophically is declared eternal law.

Kalidasa, the great poet, had a keen insight into human nature, and gently warned that the "*subtle is understood only by the subtle*". The difficulty, of course, lies not with subtlety but with us. Unfortunately, we are rarely in a subtle mood. We are far more attentive to loud conclusions than to quiet premises. **Subtlety, when it appears, is often mistaken for weakness.**

The Sacredness of Mass

For centuries, mass enjoyed an almost sacred status. One could hold it in one's hand, place it on a balance, and watch the needle settle obediently. Disagreements about mass ended quickly; the scale had the last word. Energy, on the other hand, inspired no such confidence. It hid in springs, turned into motion, and then dissolved into heat. In the same room, one person felt cold, another felt warm, and both were convinced the other was mistaken. Energy could not be held, could not be weighed directly, and rarely stayed where one expected it to be. It is hardly surprising that mass felt trustworthy while energy seemed evasive.

Candles burned. Balances balanced. No alarms were raised. Newtonian intuition survived not because it was correct, but because its errors were too small to disturb our comfort.

Rabindranath Tagore captured this gently when he wrote: "*The truth knocks softly; it is the mind that sleeps.*"

Why the Candle Cannot Reform Us

The candle does everything right. It obeys relativity. It quietly releases a portion of its rest energy. It even sacrifices its own existence to demonstrate the point. Yet it fails to reform us, because we demand something dramatic before we notice.

In the *Mahabharata*, Yudhishthira answers every question correctly, but it is Bhima's actions that people remember. Wisdom, when unaccompanied by force, rarely becomes legend. Oscar Wilde once remarked, with gentle cruelty: "Experience is the name everyone gives to their mistakes." **The candle offers experience without pain. We decline the offer**.

Visibility Is Not Understanding

We commit a persistent intellectual error: we confuse seeing with knowing. The candle's mass loss is invisible not because it is unreal, but because our senses are blunt. Nature does not recalibrate her laws to suit our instruments. Galileo warned us long ago that "*nature is inexorable and immutable*." **She does not raise her voice when we fail to listen**.

Science Waits; Humans Delay

Science is patient. Humans are not. Equations remain true whether we acknowledge them or not. The candle obeyed relativity before relativity had a name. It still does — silently, faithfully, without publicity. The nucleus, however, enforces belief. It does not persuade; it compels. Between the two stands the human mind — cautious, conservative, and deeply attached to familiar ideas. The *Mahabharata* captured this long ago: "*That which is beneficial is often unpleasant to hear*."

In Defence of the Candle

The candle has done its duty. It followed the laws of nature precisely. It released a part of its rest energy. If the lesson did not register, the fault lies not in the flame, but in the observer. The candle and the nucleus tell the same story. One speaks *softly*. The other *shouts*. Both are right. If we learn only from catastrophes, we mistake astonishment for understanding. A mature scientific attitude listens even when nature does not raise her voice. **The universe has always been honest. It is we who keep asking for emphasis.**

In Praise of the Candle

It is time we paid the candle its due. The next time we light one before students, let it be more than a source of illumination. Let it stand quietly, doing what it has

always done, while we learn to look more carefully. Let it brighten not only the room, but understanding as well — a modest reminder that even this simple flame speaks the language of modern physics. Without drama or insistence, it echoes the principles of relativity, patiently demonstrating that profound ideas need not arrive with spectacle.

We have been looking at the candle. Let us now listen to what it says:

"I am burning as I always have. My calm actions obey physics. Pay attention, and you may notice that even I echo relativity."

Acknowledgement: I thank Prof. Somashekar Sidiginamale for suggesting a correction.

Author:

Dr. K. S. Mallesh
Former Professor, Department of Studies in Physics, University of Mysore

******

A Life That Burned Quietly: Marie Curie

Like a candle that gives light without noise, **Marie Curie** worked in silence, patience, and self-effacement. In an unheated shed, with no applause and little comfort, she spent years extracting radium—slowly, painstakingly, without certainty of success.

She did not seek fame. She refused to patent her discoveries. She simply **burned quietly**, illuminating science while consuming her own strength.

Just as a candle does not announce its sacrifice, Marie Curie never spoke of hers. Yet the light she released continues to guide medicine, physics, and human thought long after the flame itself is gone.

Some lives do not blaze loudly; they shine steadily—and change the world.

Three months report of AJ Academy for Research and Development

November 2025:

1. Teachers' Evaluation conducted at Patel Public School, Hubballi. A total of 15 teachers were evaluated through classroom observation and individual meetings by a three-member team.

2. Teachers' Orientation Programme for Science, Maths, and EVS teachers organized on 15 November 2025 at Goa Science Centre & Planetarium, Panaji. Participants: 80.

3. Inter-School Science Fair organized on 20 November 2025 at Bhatkal. 165 students presented 48 research-based projects.

4. Inter-School Science Fair organized on 22 November 2025 at Hubballi. 65 students presented 45 research-based projects.

5. Inter-School Science Fair organized on 29 November 2025 at Hosapete. 150 students presented 62 research-based projects.

December 2025:

6. District-level Inter-School Science Fair organized on 20 December 2025 at Raichur. 225 students presented 110 research-based projects.

7. Exclusive study meet organized on 7 December 2025 at Mahbubnagar, Telangana. 15 students presented papers on intellectual and scientific perspectives.

January 2026:

8. Addressed a press conference on 7 January 2026 at Panaji as part of Goa State Inter-School Science Fair preparations.

9. Teachers' meet organized on 8 January 2026 at Ashiyana School, Vasco, to discuss effective teaching methods.

10. Exclusive meeting held on 8 January 2026 at Vasco for experts evaluating science fair projects. Experts were from the National Institute of Oceanography and the National Centre for Polar and Ocean Research (NCPOR).

11. State-level Science Fair organized at Madgaon on 9 and 10 January 2026 in association with the Board of Innovative Education.

12. Teachers' training conducted at Koppal and Hubballi; 34 teachers benefited.

Author: M.A. Javed, Life member, KPA & Secretary, A J Academy

KPA Activities

Sri. H. D Anand

1. 14th Dec 2025: Delivered an invited talk at Fremont Library, California, USA, on Fundamentals of Satellites and Rockets.

2. 30th Dec 2025: Conducted a webinar for JANYU Technologies, Mumbai, on Quantum Communications.

3. 10th Jan 2026: Delivered an invited talk at GSSS College of Engineering for Women, Mysore, on Quantum Computing Applications along with video demonstration.

Dr. B Rudraswamy

1. Delivered a lecture on Quantum Science and Technologies and interacted with students at Government High School, Avalagurki, Chikaballapur Taluk, on 14 November 2025.

2. Delivered a lecture on Wonders of Quantum Science and interacted with students at Niveditha High School, Kyatasandra, Tumkur, on 21 November 2025.

3. Delivered an invited talk on Nuclear Reactor and Nuclear Physics at the International Conference on Emerging Frontiers in Material Science and Radiation Physics (ICEMR-2025) held at SBMJFGC, KGF, Karnataka, on 23 December 2025.

4. Delivered a lecture on Wonders of Quantum Science and interacted with students at BBMP High School, Chamarajpet, Bengaluru, on 13 January 2026.

Dr. P Nagaraju and Dr. M S Jogad

1. Dr. P Nagaraju and Dr. M S Jogad attended ICPE 2025 held at IIT Ropar during November 16–20 and presented papers.

Dr. B A Kagali

1. Delivered a talk on Quantum Science and Technology and interacted with students at Chikballapur Government High School on 14 November 2025.

2. Delivered a talk on Quantum Science and Technology and interacted with students at Nivedita High School, Kyatasandra, on 21 November 2025.

3. Delivered a talk on Quantum Science and Quantum Technology at Jain Deemed University on 24 November 2025.

4. Interacted with students at SDC College, Kolar, on 5 December 2025.

5. Interaction with two Government School students at Mysore on 22 December 2025.

6. Delivered a talk on Variational Principles in Physics at the National Conference on Quantum Science and Material Science held at Karnatak University, Dharwad, on 16 January 2026.

Dr. B S Srikanta

1. Served as the Chief Guest at Inter-institutional (High Schools and PU Colleges) Cultural, Science and Co-curricular Activities organised by KLE PU Colleges (both aided and unaided) on 5 December 2025.

2. Served as the Chief Guest at the Annual Day celebrations of SSB International School, Indiranagar, Bengaluru, held on 6 December 2025.

3. Invited as the Chief Guest at Vijaya High School, Santhebennur, Davanagere, on 3 January 2026, and delivered a talk on the importance of science education.

4. Participated in the State-level Inter-High Schools Science Quiz Competition conducted as a part of the 29th State Level Scouts and Guides Jamborette held on 28 December 2025 at Belagavi.

******

Webinars held during 1 November 2025 to 31 January 2026

Sl. No.	Date	Speaker	Topic
1	2/11/25	Dr. Jagdev Singh	First Antarctic Expedition to study the Sun
2	23/11/25	Dr. Revanasiddappa M	Biosensors
3	30/11/25	Dr. B S Shylaja	Variable stars – why we need to study them
4	7/12/25	Dr. R S Keshavamurthy	Reactors and Artificial Intelligence
5	14/12/25	Dr. Pushpa Bhat	Tale of two discoveries – top quark and the Higgs Boson
6	21/12/25	Dr. Sarbari Bhattacharya	Optical Tweezers and their applications
7	28/12/25	Dr. Sushma Athokpam	Tellurovanadate-based glass systems
8	4/1/26	Dr. P Nagaraju	ICPE 2025 – my experiences
9	11/1/26	Dr. Nithin V	Using light to control light – optically pumped semiconductor devices
10	18/1/26	Dr. R Srikanth	Quantum information science in today's technology landscape
11	25/1/26	Dr. Shrinivasarao R Kulkarni	Space Radiation Environment and its detection