KARNATAKA PHYSICS ASSOCIATION (R)

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

Website: karnatakaphysicsassociation.in

KPA NEWSLETTER 1 NOVEMBER 2023

Editors

Basavaraj A Kagali

Somasekhara S.

S P Basavaraju

M R Nandan

Genesis of KPA

The first meeting of the proposers to set up KPA was held on 12th February 2022, at the Raman Lecture Hall, Physics Department, Central College, Bengaluru. Seventeen interested persons attended the meeting. The meeting was held under the Presidentship of Prof. G Venkatesh.

KPA was officially registered under the Karnataka Societies Act 1960 on 24th March 022, with Reg. No. DRB2/SOR/210/2021-2022 by the Registrar of Societies, 2nd circle, Bangalore Urban District, Malleswaram, Bengaluru 560003.

The ad-hoc office bearers and EC members of the Association are:

Sl No.	Name	Designation
1.	Venkatesh G	President
2.	Basavaraj A Kagali	Vice President
3.	Nagaraju P	General Secretary
4.	Raghavendran K M	Treasurer
5.	Nagaraja H S	Member
6.	Srikanta B S	Member
7.	Basavaraju S P	Member
8.	Arvind Gopal Kulkarni	Member
9.	Somasekara Siddiginamale	Member
10.	Nataraju S K	Member
11.	Nandan M R	Member
12.	Geetha R S	Member
13.	Shanthala V S	Member
14.	Shivaram Narayan Patil	Member
15.	Raghavendra Maiguru	Member
16.	Achutha B S	Member
17.	Sai Venkataraman	Member

Activities of the Association

a) Inauguration of KPA

Karnataka Physics Association was formally, inaugurated on July 27, 2022 by Padmashri A S Kiran Kumar, Vikram Sarabhai Professor and former Chairman, ISRO at Nrupathunga University (formerly Govt. Science College). Prof Shrinivasa Balli, Vice Chancellor, Nrupathunga University was the guest of honour.

In his Inaugural address, Dr Kiran Kumar said that there is a need for forming an Association like KPA to reach all corners of Karnataka for science in general and Physics in particular. Dr Kiran Kumar also delivered a talk on the topic: "SPACE – THE FOURTH FRONTIER."

b) Unveiling the KPA Website

The website of KPA was launched at MES Degree College, Malleswaram on Feb 9, 2023. After launching the website Prof. Tarun Souradeep, Director of RRI, spoke on 'Driven by Quest- Gravitational wave Science'.

Prof.Tarun Souradeep

He also briefed about LIGO-India and the ongoing research at the International level. Director of MES College Prof. Sheela Menon expressed her happiness about the new Association and invited it to conduct programmes for its teachers.

c) National Science Day Celebrations

The National Science Day of India was celebrated on 28th Feb 2023 at Sindhi College at Kempapura, Bengaluru. Sri Hiriyanna, former Scientist ISRO being the chief guest spoke on "Science and Mathematics in daily life" with some numerical examples.

Prof G Venkatesh spoke on the significance of the National Science Day and the life and contributions of C V Raman. Dr B S Srikanta, Director of the Sindhi College spoke about KPA and its objectives.

d) International Day of Light Celebrations

'The International day of Light' was celebrated in association with Maharani's Cluster University at the Maharani's Women's Science College on May 16, 2023. Prof G Venkatesh spoke on "Light and light Technologies". Prof S P Basavaraju delivered a talk on "LASERS and their applications".

Workshops & Talks organised by KPA

1. Prof G Venkatesh, Prof B A Kagali and Prof P Nagaraju were the resource persons at the summer School held at the Govt. High School, Hosagavi town, Maddur Taluk on 7th May 2022.

2. Prof G Venkatesh, Prof Somasekara S and Prof P Nagaraju along with Agastya Foundation staff demonstrated a few experiments to students of Govt. High School Mathur, near Devanahalli on 4th July, 2022.

3. Prof B A Kagali and Prof P Nagaraju demonstrated a few low cost experiments to the students of G S English High School, Bapuji Nagar, Bengaluru on August 22, 2022.

4. Prof G Venkatesh and Prof Somasekara S delivered talks on Nobel prizes in Physics 2022 at SDC College, Kolar on 10th November 2022.

5. Prof G Venkatesh, Prof Somasekara S and Prof S P Basavaraju visited the Govt. High School, Halagur, Maddur Taluk and interacted with the students of Govt. High School on December 26, 2022

6. Prof A G Kulkarni and Prof Somasekara S visited Goutham Rural School, Bande Kodigehalli and interacted with the High School students on Jan 28, 2023.

7. Prof B A Kagali, Prof P Nagaraju and Prof R S Geetha served as resource persons for the summer School at Govt. High School Hosagavi town, Maddur Taluk on April 29, 2023.

8. K P A Founder members: Dr M S Jogad, Kalaburagi; Sreenath K R, Bengaluru and Sai Venkataraman, Bengaluru are very actively conducting weekly events, either online or offline, for students.

9. B S Krishnamurthy, life member of KPA from Mysore is doing commendable work in teaching Mathematics through his special 'Ganitha-Kunitha' programmes at various Schools and Colleges.

10. KPA cosponsored the 100th lecture organized by 'Cre Active' at the Karnataka Open University, Mysore on July 2, 2023. Prof G Venkatesh, Prof B A Kagali and Prof P Nagaraju participated at that person programme.

11. K P A, in association with M S Ramaiah Pre University College, conducted a workshop for High School and PU College teachers at the M S Ramaiah Pre University College on July 13, 2023. Prof G Venkatesh, Prof B A Kagali, Prof P Nagaraju and Prof B S Achutha served as resource persons. The workshop was an interactive one with experimental demonstrations. About 50 High School and pre-university teachers from both Government and Private College participated.

12. Prof B A Kagali and Prof P Nagaraju demonstrated a few low cost experiments at JSS High school, Banashankari, Bengaluru on 4th August 2023 for English medium students.

13. Prof B A Kagali and Prof P Nagaraju demonstrated a few low cost experiments at JSS High school, Banashankari, Bengaluru on 11th August, 2023 for Kannada medium students.

14. Prof G Venkatesh has delivered lectures at the following institutions on various topics listed below:
(i) 'Niels Bohr and Quantum revolution' at AES National College, Gauribidanur on 10th Feb 2023
(ii) 'Niels Bohr and Quantum revolution' at Indian Academy Degree College, Hennur cross, Kalyannagar on 7th November 2023.
(iii) 'Makers of 20th Century Physics' at Govt. First Grade College,Vijayanagar, Bengaluru on 4th July 23.
(iv) 'Max Planck to Paul Dirac – the story of Quantum Mechanics' at National College, Bagepalli on 2nd August 2023.

15. Prof S P Basavaraju gave a talk on 'Life of Sir C V Raman' at National College, Bagepalli on 2nd August 2023.

16. Prof S P Basavaraju and Prof S K Nataraju seved as judges for the Poster presentation competitions for students in view of the National Science Day celebrations at the National College, Gauribidanur on 25th February 2023.

17. Prof G Venkatesh and Prof S P Basavaraju were the judges for the models and posters competition for students on the "successful lunar mission", organized at Sri G Hallikeri First Grade College, Haveri on 28th July 2023.

18 Prof K M Raghavendran delivered a talk on "Life and works of Sir C V Raman" and also demonstrated experiments on scattering and polarization to 9th and 10th standard students of MES Kishore Kendra School, Malleswaram on November 12, 2022.

19. Prof Somasekara S served as the Resource Person "For experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information Science" – An interactive session with teachers from Maharashtra at Agastya Foundation, Kuppam Campus on October 12, 2022.

20. Prof Somasekara S has gave a talk (on line mode) on "Nature of Light, Light Technologies and Light therapy" to High School Teachers of Maharashtra State on May 20, 2023.

The First Annual General Body Meeting of KPA

The first AGBM of KPA was held on 10th Sepember, 2023 at National College, Basavanagudi, Bengaluru 560004.

Members present in the meeting:

1.	Dr. G. Venkatesh	President
2.	Dr. Basavaraj A Kagali	Vice president
3.	Dr. Nagaraju P	General Secretary
4.	Prof. Raghavendran K M	Treasurer
5.	Dr. Nagaraja H S	Member
6.	Dr. Srikanta B S	Member
7.	Dr. Basavaraju S P	Member
8.	Dr. Somasekara S	Member
9.	Prof Nandan M R	Member
10.	Dr. Shivaram Narayan Patil	Member
11.	Dr. Raghavendra M K	Member
12.	Sri. Achutha B S	Member
13.	Dr. Jogad M S	Member
14.	Dr. Nagabhushan C	Member
15.	Dr. Sreenath Rathnakumar	Member
16.	Prof.Sudheendra H S	Member
17.	Prof. Bhojraj	Member
18.	Sri. Basavaraju J	Member
19.	Sri Nazeer Ahmed	Member
20.	Sri Liyakhat Ali Khan	Member

The meeting began with the General Secretary Dr. Nagaraju P requesting the President Dr. G. Venkatesh to chair the meeting. The president called the meeting to order and took up the agenda.

Item1. President's welcome address and speech: The President began by thanking the management of NES for providing the Dr. H.N multimedia hall at National College Basavanagudi to conduct the AGM. He started with an apology for not including the salutation of all life members by oversight. He congratulated the General **S**ecretary for drafting the report and the Treasurer for getting it neatly formatted and printed. He then welcomed all the members to the AGM and requested them to introduce themselves. Dr. Somasekara mentioned that a thanking letter should be sent to the management of Indian Academy PU **Co**llege for providing the space for the office of KPA. The President asked the **S**ecretary to do the needful. He also thanked Prof. Sudheendra of Nrupathunga University for making all the arrangements for the inauguration of the Association and Dr.Usharani.D, Principal MES College of Arts, Commerce and Science, for hosting the launch of the KPA website at MES College. After the introductions he requested the General Secretary to present the annual report for acceptance.

Item 2. Consider and accept the Annual Report of KPA for the year 2022-23: Dr.P.Nagaraju, the General Secretary, started his presentation by mentioning that since the preparation of the report, seven more life members have joined and specially mentioned the names of two student members of the **As**sociation. He then presented the annual report of KPA, which had earlier been circulated as a pdf and a printed copy of which was given to all the members. He made a special mention of founder member Dr. M. S. Jogad from

Kalaburagi, Sreenath K. R. from Bengaluru, and Sai Venkataraman from Bengaluru who are actively engaged in conducting, both online and offline, events on a weekly basis; and B. S. Krishnamurthy, a life member of KPA from Mysore, who is making commendable efforts to popularize mathematics among school children. He then invited comments and observations on the report from the members.

After the presentation of the report by the General Secretary, the president requested one of the members to propose its acceptance and another to second the same.

Dr. Somasekara S. proposed the acceptance of the annual report of KPA for the year 2022-23. The proposal was seconded by Prof. Nandan M R and it was accepted by all the members.

Resolution: "Resolved unanimously that the Annual Report of KPA for the year 2022-23, already circulated to the members and presented in this meeting be and is hereby accepted"

Item 3. Consider, approve and adopt the audited statement of Accounts of KPA for the year 2022-23 of KPA for the year ended 31st March 2023, along with the Auditors Report.

The Treasurer presented the audited statement of accounts and the independent auditors report. He reported that the auditors also considered, this being the first year of the existence of the association, all expenses from February 2022. He clarified that the income to the Association is solely from membership fee and as of now, the Association cannot seek donations. However, the Association can seek sponsors for various events organized by it. He also reported that the Association has obtained a PAN: AAJAK9378B and has also registered for online filing of IT returns.

Dr. H. S. Nagaraja, EC member, suggested that we might approach corporates or philanthropists to sponsor specific events organized by it. The president requested the members to accept and adopt the audited statement of KPA for the year ended 31st March 2023 along with the Auditors Report already circulated to them as the same is to be filed before the Income Tax authorities before 30.09.2023.

He requested one of the members to propose its acceptance and another to second the same.

Dr. M S Jogad proposed the acceptance and adoption of the audited statement of accounts of KPA for the year ended 31st March 2023. The proposal was seconded by Dr. S P Basavaraju and it was then accepted by all the members.

Resolution: "Resolved unanimously that the Audited statement of Accounts of the KPA for the year ended 31st March 2023 consisting of the Income and expenditure statement and Balance sheet as on that date, along with the independent Auditor's Report, already circulated to the members and presented at this meeting is hereby approved and adopted".

Item 4.Appointment of Statutory Auditors for the year 2023-24

Dr. G. Venkatesh, the president of KPA apprised that the Auditors: NAINEGLI & Co have done a good job in completing the audit for the FY 2022-23 and submitting the audited statement of accounts. He suggested the continuation of the auditors for one more term for the FY 2023-24 and requested the house to authorize the President and Treasurer to fix the terms and conditions including remuneration.

Resolution: "Resolved unanimously that M/S NAINEGLI & Co be and hereby appointed as statutory Auditors for the FY 2023-24 on the terms and condition to be approved by the President in consultation with the Treasurer"

Item 5. Election/Nomination of new office Bearers and EC members

The term of the existing EC and office bearers is only till the day of first AGM or till the election of office bearers and EC members for the next term. Since the membership from

various divisions is very poor, it was decided to have a vigorous membership drive by all the EC members. Till such time, the General Body resolved to defer the elections and asked the present Office Bearers and EC members to continue, until the next meeting is called for the purpose of elections. Hence the following resolution was passed.
Resolution: "Resolved unanimously that the existing committee will continue till the next meeting is convened. As per the byelaws of the Association a 4(four)-member election committee was constituted. The committee is authorized to draw up the calendar of events for the elections and publish the same in the Association website and fix the date of the elections/nominations to the posts of office Bearers and EC members."

The approved election committee consists of the following members:

1. Prof. H S Sudheendra Returning officer
2. Prof. V Jagadish Member
3. Dr. J Abhiram Member
4. Sri. Naveen K R Member

Item 6. Proposed activities for 2023-24
The following are the main observations and suggestions from the members for strengthening the activities of the Association, which were discussed and adopted.
1. Intensifying efforts to increase the membership to the Association.
2. Creating a corpus fund for the Association through CSR contributions by corporates / donors and getting sponsorship for specific events.
3. Dr.M.K.Raghavendra agreed to share the license of Zoom platform for KPA online programs and also agreed to create a YouTube channel for the Association. He also suggested that KPA should focus on student centric activities that are hands on in nature.
4. Dr. Sreenath Rathnakumar offered to take KPA as cohost for Physics online programs conducted by 'CreActive'.
5. Prof Achutha B S suggested conducting an Olympiad program for high school students.
6. The Treasurer suggested that there should be an IT team to take care of website and all online activities of the Association.
7. It was also suggested by the Treasurer that a part of the membership fee could be invested in the form of an FD in the bank and the interest earned thereof may be used for activities of the Association.

Item 7 ***Any other matters with the permission of the chair.***
There being no other matter, the meeting concluded with a formal vote of thanks to the Chair and members by Dr. B. A. Kagali, Vice President of the Association.

HOW RAMAN EFFECT WAS DISCOVERED

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

Abstract: Even though many people know about Raman effect, many do not known that it took nearly seven years of intense and sustained research work by C V Raman and his research students for the discovery of the Nobel Prize winning discovery that is now named after Raman. This article is a brief account of their efforts on the occasion of the birth anniversary of Raman that falls on 7th of November.

C V Raman was appointed as the first Tarakanath Palit Professor of Physics in Culcultta University in 1917. He was also working at the same time as the Honorary Secretary of the Indian Association for the Cultivation of Science (IACS), a non-governmental organisation set up for the promotion of science. He kept himself busy from early morning till late night with teaching and research work. One of the conditions laid down by the donor of the Palit chair was that the appointee should have been 'trained' abroad. Professor Raman was not 'trained' abroad and he refused to go to England for 'training' to meet the requirements of the appointment! It is alleged that Raman told the appointing authorities that he was competent to 'train' the foreigners in India instead of getting himself trained by them! Sir Ashutosh Mookerjee, the influential Vice-Chancellor of the University, who was looking for the best scientists for Calcutta University amended the provisions of the endowment at the time of appointment for C V Raman thereby facilitating the latter's appointment.

Visit to England

However, in 1921, Mookerjee prevailed upon Professor Raman to go to England as a 'delegate' to the Universities Congress held that year in Oxford. By that time, Raman had already published several research papers in acoustics and optics and his work was well-known and appreciated in the scientific circles of England and the Continental Europe. During that visit, Raman met and had discussions with several famous English physicists such as J. J. Thomson, E. Rutherford and W. H. Bragg. During his short stay in London, he visited St. Paul's Cathedral and was fascinated by its whispering galleries. He went ahead to carry out a few experiments in collaboration with one Mr. Sutherland and before his return to India published his findings in the form of two papers – one in Nature and the other in Proceedings of the Royal Society.

Colour of the Sea

It was during that sea voyage that Professor Raman saw for himself the deep blue colour of the Mediterranean Sea. It kindled in his mind the early wonder at the blue of the Bay of Bengal that used to be observed from the beaches of Vishakpatnam and Madras. In the scientific literature, Lord Rayleigh had successfully explained the blue colour of the sky as due to the scattering of sunlight by the molecules of Oxygen and Nitrogen present in the atmosphere. H dark blue of the deep sea is simply the blue of sky seen by reflection." Gazing the deep blue colour of the sea, Raman felt that Raleigh's explanation was not satisfactory. On his return voyage he carried with him a polariser - a Nicol prism. The reflected light from the sea, at a particular angle of reflection – which is nothing but the Brewster's angle in optics - would be completely plane polarised and therefore would be capable of being extinguished by a suitably oriented Nicol prism. Professor Raman found through his observations, to his great surprise, that such extinguishing did not take place – instead, the sea was glowing with a strong blue colour. Obviously, the light from the sea was not just the reflected light of the sky but had a component that was coming from the inside of sea water itself!

Research Work initiated

On his return to Calcutta in September 1921, Raman started testing the explanation that sunlight was getting scattered by sea water. He soon realised that the subject of light scattering by liquids was more significant than just explaining the colour of the sea. Thus Professor Raman initiated research work in IACS in the following areas: 1. the scattering of light by liquids, 2. the scattering of X rays by liquids and 3. the viscosity of liquids.

In December 1921, K R Ramanathan, one of the most gifted of Raman's collaborators joined him as a research scholar of Madras University. For his outstanding scientific contributions during the course of a single year, Madras University conferred on Ramanathan its D. Sc. Degree.

Dr. Ramanathan was involved in both the fields of study - scattering of light by the liquids and scattering of X-rays by liquids. They did not pursue X- ray scattering by liquids after contributing an important paper that was published in 1923. Professor Raman has often stated that ambition, courage and endeavour had been his watchwords. Thus he devoted his entire time and energy studying the scattering of light by liquids, gases and solids from then onwards. He published a comprehensive essay on the molecular scattering of light that was promptly published by the Calcutta University Press. Raman was elected a Fellow of the Royal Society of London in 1924. The University of Calcutta threw a dinner to felicitate him on that recognition. Sir Ashutosh jokingly asked Raman: "what next?" Raman quickly replied: "Nobel prize!"- that was the level of self-confidence Raman possessed in his ability and work.

Raman had taken up residence adjacent to the premises of IACS at 210, Bow Bazar Street, Calcutta to cut down his travelling time. Later he got a door installed in the wall of his residence so that he could enter and leave the laboratory at any time of the day or night from his residence.

As mentioned earlier, Professor Raman's voyage across the Mediterranean Sea in the summer of 1921 had set his mind on the molecular scattering of light by liquids. Within a few weeks of his return, Raman and Mr. Sheshgiri Rao measured the intensity of the molecular scattering of light from water. They established that the Einstein- Smoluchowski concept of random clustering of molecules could be extended to explain molecular scattering almost quantitatively.

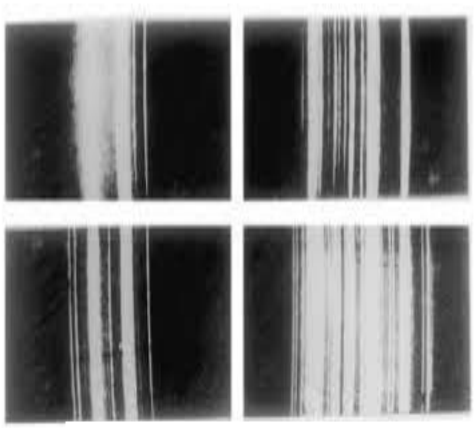
Observations by Research Students

Even before the discovery of the Compton effect, that was observed in 1923, Raman had thought of the interaction of light quanta with the molecules of matter in which energy transfer could take place between light quanta and molecules. In April 1923, at Raman's suggestion, Dr. Ramanathan made a detailed study of the scattering of light in water. Sun light was focussed on the liquid and the scattered light when viewed from a transverse direction to that of the incident beam, was seen as a track inside the liquid. A system of complimentary filters was devised - each filter completely cutting off the light transmitted by the other. Ramanathan observed a change in the colour of the scattered beam having a very low brightness. He attributed it to a "weak florescence" perhaps due to impurities which were believed to be present.

However, in spite of repeated purifications and the use of different kinds of purified liquids, the phenomenon of "weak florescence" persisted. It involved a change of colour. Such experiments continued to be perfomed by different workers in the laboratory during the next five years, notably by K S Krishnan and S Venkateswaran. A large number of solids, liquids and vapours were used as the scattering media. They all showed the "weak florescence" in varying degrees. However, Raman was not satisfied with the general explanation of "weak florescence" in the scattered light.

Venkateswaran, on one occasion, observed during his studies that the scattered light from glycerene was having a higher wavelength than the incident one and also polarised- an important clue that lead to the conclusion that the "weak radiation" was not due to florescence but due to genuine scattering process.

The work of A. H. Compton in X-ray scatering for which 1927 Nobel prize was awarded had gained general acceptance for the idea that scattering of radiation was a process in which energy and momentum were conserved. It made Raman think of a similar effect in the optical region. On a few occasions when he found the bright track in benzene in the experimental arrangement set up by Mr. K S Krishnan, Raman used to be puzzled by the "florescence" explanation. It was late in February of 1928 when studying the light scattered by pure benzene using incident sunlight that it suddenly occurred to Professor Raman's mind that they should use mercury vapor light as source and to view the "fluorescent" track through direct vision spectroscope. A Zeiss Cobalt -glass filter placed in the path of the incident beam from mercury arc cut off all visible light of wavelengths longer than that of the bright violet indigo region present in the incident beam.



The first recorded spectrum of scattered light from benzene

In the spectra of light scattered by benzene, a bright band in the blue- green region was observed by Raman, that was separated by a dark interval from the indigo violet region transmitted by the filter. Both of these regions the spectrum of scattered light became sharper when the region of transmission was narrowed by the insertion of an additional filter in the incident beam. The experiment was repeated with a variety of liquids and solids and the startling observation was made that the spectrum of the scattered light generally contained a number of sharp lines or bands on a diffuse background which were not present in the incident light of the mercury arc. It was a “new type of radiation” due primarily to the inelastic scattering of radiation by molecules. All this happened conclusively on February 28, 1928.

Announcing the Discovery

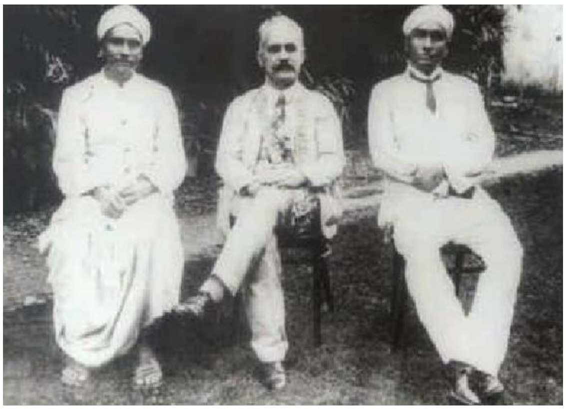
The announcement of the discovery of the “new type of radiation” was made to the Associated Press in Calcutta on February 29, 1928. The announcement happened because Professor Raman was very confident about significance of the discovery. Then a note sent was to the journal ‘Nature’ on March 8th by Raman and Krishnan announcing their discovery. Strangely, it was rejected by the referee, but the editor, Sir Richard Gregory, published it in the April issue of the prestigious journal, recognising its significance! This is the now famous “Raman effect”. Within a short time, it was confirmed by several laboratories around the world. Prof. R. L. Woods of Johns Hopkins University in USA communicated his confirmation to ‘Nature’ and stated that it was a beautiful validation of quantum theory. Two other research groups – one in France and the other in Russia also discovered equivalent effects just a few months later- however, Raman had won the race!

The quartz mercury lamp was so powerful and convenient source of monochromatic illumination that in the case of liquids and solids photographing the spectrum of scattered light was found to be easy. The earliest pictures of the phenomenon were taken with a Hilger Baby Quartz Spectrograph.

The first spectrograph used by Raman

Then onwards, many laboratories in the world took up the study of the Raman effect in simple molecules. But in Raman’s laboratory emphasis was on the study of more fundamental problems connected with the physics of liquids and solids state using Raman effect as a tool. Professor Raman was knighted by the British government in 1929. The entire equipment used for discovery cost less than two hundred Rupees- a mercury lamp, a flask of benzene and direct vision spectroscope. Several years later when reminiscing about the discovery Professor Raman remarked: “the essence of science is independent thinking, hard work and not expensive equipment”. Conditions have apparently changed over time and nowadays expensive equipment is perhaps necessary for making fundamental discoveries

Professor Arnold Sommerfeld of Germany visited Calcutta and Raman’s laboratory in October 1928 on his way to USA. Being impressed with the work done there with limited facilities and resources he apparently recommended Rama's name to the Nobel committee for its honour. Several others also suggested Raman's name for the prize. Hence, Raman was awarded the Nobel Prize in physics "for his work on the scattering of light and for the discovery of the effect named after him" in the year 1930. Thus ended a long quest of Raman and his collaborators in understanding the radiation scattered by molecules of matter and showed a new way for in deducing the structure of molecules. After the invention of lasers, Raman effect has become an indepensible tool for physicists and chemists.



K S Krishnan, A Sommerfeld and C V Raman,1928

References

1. P. R. Pisharoty, C. V. Raman, Publication Division, Govt. of India, New Delhi, 1982.
2. G. venkataramn, Raman and His effect, Universities Press, Hyderabad,1995.
3. A. Jayaraman, C. V. Raman – A memoir, Indian Academy of Sciences,Bangalore, 2017.
4. https://www.aps.org/publications/apsnews/200902/physicshistory.cfm

C.V. Raman: A Dedicated Mentor Who Shaped the Careers of Young Scientist

One notable aspect of Raman's interactions with his students was his emphasis on encouraging their independent thinking and fostering a spirit of scientific curiosity. He believed in hands-on experimentation and encouraged his students to question established scientific principles and think critically.

Raman's approach to teaching and mentorship was not only about imparting knowledge but also about instilling a deep love for science and a passion for discovery. Many of his students went on to make significant contributions to the field of physics and other scientific disciplines, thanks in part to his guidance and mentorship.

One of his most famous students, Subrahmanyan Chandrasekhar, also became a renowned physicist and made important contributions to our understanding of the structure and evolution of stars. Raman's impact on the scientific community extended not only through his own research but also through the scientists he mentored and inspired.

WORLD'S BEST-KNOWN WOMAN SCIENTIST

Dr. S. P. Basavaraju
Professor of Physics (retd.), BIT, Bengaluru

1. Early life

Marie was born as Manyusva Sklodovska at Warsaw in Poland, on Nov 7, 1867. Her name was shortened as Manya Sklodovska. Sklodovska was her family name.

In her family, totally, they were 5 children. Among them, Zosia was the eldest, who died due to Typhus when Marie was 8 Years old. Manya's beloved mother died due to Tuberculosis when Marie was only 10 years old.

When Manya was 18, she started working as a governess and a tutor for an affluent family. In 1891, she went to Paris with some savings. There she joined the University of Paris which is generally referred as Sorbonne in France. Inspired by the achievements of Louis Pasteur, Manya dreamt of a career in science. She registered as a student of science. She changed her name to Marie Sklodowska (Marie being a familiar French name).

In summer 1893, Marie finished as top student in her physics Master degree course. In 1894, she received a degree in mathematics, securing second top place. She also completed a master's degree in chemistry in 1894.

She was awarded a scholarship earmarked for an outstanding Polish student. Before completing the math degree, she was also commissioned by the Society for the Encouragement of National Industry to investigate how the composition of steel affected its magnetic properties. The idea was to find ways of making stronger magnets. She needed to find a lab where she could do the work.

She knew a Polish professor of Physics who in turn talked to his colleague Pierre Curie, who was the lab chief in his school about Marie's requirement. Pierre Curie agreed - following which, Marie found some basic space to carry out her studies in the Municipal school.

In the year 1895 she began working for a Ph.D. degree in physics. By then, Pierre Curie wasged 35. Earlier, when he was 21, he had discovered piezoelectricity with his brother Jacques. He was also an expert in magnetism. He had discovered the effect now called the *Curie Point*, where a change of temperature has a large effect on the properties of a magnet. In fact, Langevin who gave the theory for Dia and Para magnetism was his student.

2. Marriage and Research Work

Pierre had admired Marie and timidly proposed marriage to Marie With equal timidity, Marie consented. On July 26, 1895, Marie Sklodowska married Pierre Curie in a simple civil civil ceremony and became Marie Curie!

They bought a pair of bicycles (purchased with a wedding gift) for hort weekend trips to the countryside, when they went picnicking. 1896 was the year when many things were happening rapidly in Physics.

On March 1, 1896 Becquerel observed fogging of photo - plates due to Uranium ores in a mineral called Pitch Blende. it occurred pretty much more than the usual proportionality. Hence, Becquerel assigned its investigation to Marie. He wanted her to verify if it was Uranium alone that emitted the new rays.

Pierre had discovered a new kind of electrometer that could measure extremely low electrical currents. Using that electrometer, she studied not only the radioactivity in Uranium but also in essentially all the elements known then (more than 80). Then she found that Thorium is much stronger than Uranium itself. While such things were in progress, they had their first child named "Irene" - in Sept 1897**.** By her investigations, Marie Curie confidently proposed that *pitchblende contains some hitherto unknown radioactive element in amounts that are not amenable to chemical reaction".* So that was a great breakthrough! Pierre Curie pitched in (abandoning his research work on crystal growth) in March 1898.

The Curies wrote to the Austrian Govt. requesting for the Uranium extracted ore tailings. The Austrian officials obliged and sent one ton of Pitchblende (*from which Uranium is already extracted).* The Curies also got another 10 tons acquired for them by the multimillionaire Baron de Rothschild.

They boiled and cooked great mounds of dirt; filtered and separated one impurity after another impurity. While sorting out the residues of the ore -called ore tailings- they arrived at a small amount of Bismuth salt which showed the presence of a highly active element 300 times more potent than Uranium! Isolating it in July 1898 from Bismuth, they named it a Polonium named after Marie's native country Poland**.** After several hundred crystallizations, the extract dwindled to small amounts that could fit inside a flask, and then incredibly, into a test tube! The activity of the chemical stuff, whatever that was inside, out beat that of even Polonium. They were there ……… almost at it. Finally in 1902, they secured the salt of a very, very, highly radioactive element -but just one tenth of a gram of it. The Curies decided to name the new element Radium. Anyway, it was still the salt of Radium what they had prepared. That was the yield from nearly 10 tons of pitch blende. This mega-scientific work, perhaps the only one of its kind in human history, made the Curies world famous. Recognizing this monumental achievement, the third ever Nobel prize in physics was awarded to them in the year 1903.

Henry Becquerel, Pierre Curie, Marie Curie

Marie Curie became the first woman Scientist – ever to win a Nobel Prize.

Very soon they welcomed their second daughter (1904). When everything seemed to be perfect for a happy life, a great tragedy struck the family. Unfortunately, Pierre Curie died in a road accident. Then, Sorbonne appointed Marie as a Professor in place of Pierre. Marie continued her work to confirm that Polonium too was a new element.

Now for Marie, there was that monumental job still awaiting for her - the element Radium must be isolated - in a state uncombined with any other element. In 1910, she passed an electric current through Radium chloride. She collected the amalgam formed at the negative electrode and heated with nitrogen in a silica tube under reduced pressure. There it was-the brilliant white globules of Radium! 12 years since the beginning of her relentless work, was her dream fulfilled - she saw a silvery drop of pure metallic radium weighing just 0.0085 gram. But the drop was 3 million times more radioactive than the same drop of Uranium.

The Nobel Prize for the year 1911, this time for Chemistry, but without any sharing it was awarded to this Great Lady. Marie Curie became a celebrity even among the Nobel Prize winners for winning it for the second time.

3. Worldwide Recognition

Marie Curie continued her work by teaching and researching. She is shown below in her laboratory in 1920, the year that she established the Curie Foundation to explore medical uses of Radium. Her daughter Irene was working with her side by then.

In 1920, Mrs. William Brown Meloney, editor of an American women's magazine, formed a committee called "Marie Curie Radium Campaign" and raised nearly $200,000. That money was enough to purchase a gram of Radium (priced at $100000) -which was to be presented to her by none other than Harding - the President of the United States at the White House !Funds left over, provided Mme. Curie with a life income.

In 1921, 53-year-old Marie, travelled from Paris to New York with her two daughters, Irene aged 23, and Eve, aged 16 at the invitation of 'Marie Curie Committee'.

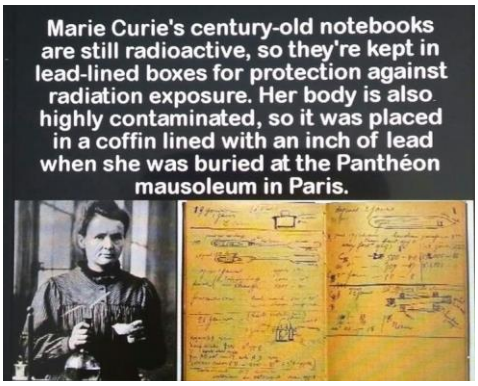
President **Warren G. Harding**
with **Marie Curie (May 20, 1921)**

Thanks to the Marie Curie's Radium Campaign, she returned to Paris with ores, costly apparatus, and cash for her institute, in addition to the gram of Radium.

In 1920 Curie and a number of her colleagues created the Curie Foundation, whose mission was to provide both the scientific and the medical divisions of the Radium Institute with adequate resources. Over the next two decades the Curie Foundation became a major international force in the treatment of cancer.

4. Last days

Many years passed. With the passing of time, her health deteriorated. By 1930, Marie Curie's vision was failing, and she moved to a sanatorium, where, her daughter Eve stayed with her.



Aged Marie Curie before bidding a final goodbye to humanity

She developed Leukemia due to what came to be known later as 'Radium Poisoning', and became extremely weak. As countless number of her admirers watched helplessly, her untiring watchful eyes were closed for the last time on July 4, 1934. However, she continues to this day as the best-known woman in the world of all times.

Marie Curie: A Pioneer in Science and a Champion of Knowledge

Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less."

"I am among those who think that science has great beauty. A scientist in his laboratory is not only a technician: he is also a child placed before natural phenomena which impress him like a fairy tale."

"You cannot hope to build a better world without improving the individuals. To that end, each of us must work for his own improvement and, at the same time, share a general responsibility for all humanity, our particular duty being to aid those to whom we think we can be most useful."

"I was taught that the way of progress was neither swift nor easy."

"I am one of those who think like Nobel, that humanity will draw better than evil from new discoveries."

HOW NEWTON DEDUCED THE LAW OF GRAVITATION

K.M. Raghavendran
Associate Professor in Physics (Retd.)
MES College of Arts Commerce and Science, Malleswaram, Bengaluru

"*After dinner, the weather being warm, we went into the garden and drank Thea, under the shade of some apple trees only he and myself. Amidst other discourse, he told me, he was just in the same situation, as when formerly the notion of gravitation came into his mind, "why should that apple always descend perpendicularly to the ground," thought he to himself: occasion'd by the fall of an apple, as he sat in a contemplative mood* "[1]

The Bubonic Plague ravaged England between 1665 and 1666, prompting Isaac Newton to retreat to his family farm. Cambridge University had closed its doors at the time due to the outbreak. During his year and a half on the farm, he enjoyed the freedom to ponder and meditate on his studies, particularly Kepler's laws and Galileo's concepts of inertia and motion, which he had delved into during his undergraduate years at Cambridge. It was during this period that he achieved a remarkable feat: formulating a mathematical description of the universal force of gravity.

At the time, the prevailing notion was that gravity was a force limited to terrestrial objects close to the Earth's surface. However, in his family's apple orchard, Newton unearthed a groundbreaking revelation—gravity extended far beyond the Earth. It reached the Moon, the planets, the stars, and even beyond. Sir Isaac Newton's profound exploration of gravity was deeply rooted in his comprehension of the interplay between motion and force, which he distilled into the three laws of motion.

The first law, or the law of inertia, asserts that nothing moves without the influence of force, and an object persists in uniform motion unless an external force acts upon it. This principle encapsulates the essence of unchanging or uniform motion.

On the other hand, accelerated motion occurs when there is a change in an object's speed or direction, and the correlation between this acceleration and the applied force is the essence of the second law. This law succinctly expresses the relationship as force equals mass multiplied by acceleration.

The third law introduces the concept that forces always manifest in pairs, acting in equal and opposite directions simultaneously. When you exert force on an object, it exerts an equal and opposite force on you.

In essence, Newton's idea about gravitational force can be summarized as follows: When an apple detaches from its branch, it descends vertically to Earth, regardless of the tree's location on the planet. Evidently, there exists a gravitational force that draws the apple towards the

Earth's centre. However, should one pick up the apple and launch it horizontally with a certain velocity, as Galileo had previously noted, the apple follows a parabolic trajectory. The more forcefully the apple is thrown, the faster it moves, covering a greater horizontal distance.

Newton's pivotal realization was that with a sufficient initial velocity, the apple could enter orbit, perpetually falling but simultaneously moving horizontally, thereby revolving around the Earth. *That's what the Moon is doing, it's going around the Earth, constantly falling, but it has sufficient horizontal velocity to keep it in orbit.* (Fig 1[2])

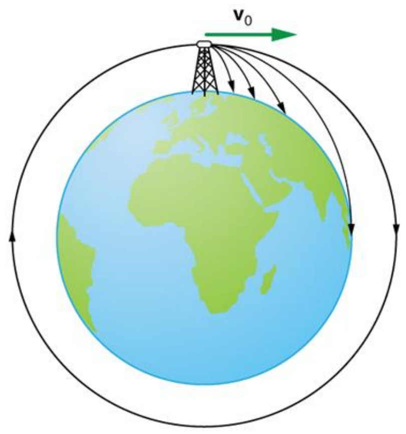


Fig.1 orbital motion is a special case of projectile motion !

Of course, to continue in orbit it must experience a centripetal force, the origin of which is clearly gravity as after all, the moon is continuously falling!

Introduction: In essence, Newton's profound insight lies in his recognition that the apple's fall to the ground and the distant moon's orbit both involve an acceleration towards the Earth's center. He aptly termed this compelling force the "gravitational force." By comparing the magnitudes of acceleration experienced by the apple and the moon, he discerned a vital clue regarding the gravitational force's dependence on distance. Newton's comprehensive examination, which took into account the second and third laws of motion, as well as meticulous experiments involving falling objects, offered valuable insights into the force's dependence on mass. Let's delve deeper into these compelling arguments.

1. Dependence of gravitational force on distance

Let us for simplicity assume the moon to move in uniform circular motion around the earth as shown in Fig 2[3]

The moon will experience a centripetal acceleration, whose magnitude is,

$$a_c = \frac{v^2}{r}$$

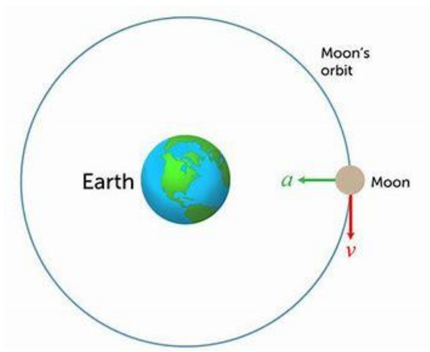


Fig 2 . The moon in a circular orbit experience a centripetal acceleration

Where "v" is the orbital speed of the Moon, and "r" is the distance between the cente rs of the Earth and the Moon. Given our assumption that the Moon is in uniform circular motion, its instantaneous speed at any moment equals to the average speed over any interval. If we denote "T" as the orbital period of the Moon, we can calculate its average speed as follows:

$$v = \frac{2\pi r}{T}$$

Using the above two equations we have

$$a_c = \frac{4\pi^2 r}{T^2}$$

Both r and T can be found from astronomical observations. Using the values of the lunar orbital radius (r = 3.84×10^8 m) and the orbital period of the moon (T = 27.3 days = 2.36×10^6 s) we obtain,

$$a_c = 2.72 \times 10^{-3} \text{ m s}^{-2} \text{ ,which is less than } 3 \text{ mm/s}^2$$

The acceleration due to gravity near or on the earth's surface is 9.81 ms^{-2}. Thus, we have

$$\frac{a_{on\ the\ earth's\ surface}}{a_{at\ the\ distance\ of\ the\ moon}} = \frac{9.81}{(2.72\ x\ 10^{-3}\ )} \approx 3600\ = 60^2$$

Now here is the simple genius of Newton's mind. He realized that the distance of the moon from the earth is nearly 60 times the radius of the earth!

$$\frac{radius\ of\ moon's\ orbit}{radius\ of\ earth} = \frac{r}{R} = \frac{3.84\ x\ 10^8}{6.37\ x\ 10^6} \approx 60 \text{ Thus}$$

$$\frac{a_{on\ the\ earth's surface}}{a_{at\ the\ distance\ of\ the\ moon}} = \frac{r^2}{R^2}$$

Newton's deduction can be succinctly summarized as follows: The acceleration an object experiences decreases in inverse proportion to the square of the object's distance from the source of the force. Considering that acceleration is directly proportional to the force acting upon the object, ***the logical outcome is that gravitational force decreases inversely as the square of the distance between the object and the source of the force.***

2. Dependence of gravitational force on mass

The one common physical property of the earth and moon is their mass. Newton felt it was reasonable to assume that the mass also plays a role in the magnitude of the gravitational force they exert on each other (the force must be mutual as per the third law of motion, equal in magnitude but oppositely directed). In other words, if M and m are the mass of earth and moon respectively then,

$$\boldsymbol{F_{M\ on\ m}} = -\boldsymbol{F_{m\ on\ M}}$$

Now newton argues that if the magnitude of the gravitational force depends on the masses of *both* the earth and the moon , it must do so in a *symmetric* manner such that, if the masses are interchanged in the gravitational force law, the magnitude of the force on each object (Earth & Moon) should remain unchanged.

Mathematically the force could depend either on the *sum* of the masses (M+m) or the *product* of the masses (Mm) or maybe on some power of (M+m) or (Mm). In other words $(M+m)^n$ or $(Mm)^n$. The simple logic being that these forms $(M+m)^n$ or $(Mm)^n$ remain the same if the masses are interchanged in their algebraic positions in the expression for the force. Now here comes the next instance of the simple genius of Newton's mind. He argues that from the consideration of the second law of motion and experiments on falling bodies we can rule out all the possibilities except the first power n =1.His arguments is as follows:

From Galileo's experiments, which can be replicated today with even greater precision, we have acquired a fundamental understanding: the acceleration of any object with mass "m," solely under the influence of the gravitational force exerted by another mass "M" (such as the Earth, for example), remains entirely independent of the object's own mass. In other words, whether it's a stone, feather, or paper, they all descend at the same rate during free fall in a vacuum. Now, if we assume that the magnitude of the gravitational force between two masses depends on the sum of these masses raised to a certain power "n," and there exists a constant of proportionality "K," then when gravitational force is the sole influence on "m," we can derive the following relationship from the second law of motion:

$$F_{grav} = m\,\boldsymbol{a}_{grav}$$

And so $$K(m+M)^n = m\,\boldsymbol{a}_{grav}$$

Which gives $$\boldsymbol{a}_{grav} = K\frac{(m+M)^n}{m}$$

This means the magnitude of the acceleration depends on *m* no matter what the value of n happens to be, which contradicts experiment!

On the other hand, if we assume the gravitational force of M on m depends on the product of the masses raised to some power *n* then we have.

$$F_{grav} = m\,\boldsymbol{a}_{grav}$$

$$K(mM)^n = m\,\boldsymbol{a}_{grav}$$

$$\boldsymbol{a}_{grav} = K\,M^n m^{n-1}$$

The magnitude of the acceleration ***can be independent of m*** if and only if **n =1!** Brilliant isn't it? Hence the gravitational force must depend on the product of the masses, namely Mm.
Combining the distance dependence and the mass dependence into a single relation we can conclude that the magnitude of the gravitational force between two masses must be directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

$$F_{grav} \propto \frac{Mm}{r^2}$$

Or

$$F_{grav} = G\frac{Mm}{r^2}$$

The above is the mathematical expression of Newton's law of Gravitation. The gravitational force is attractive, and its direction is along the line joining the two masses. The constant G is known as the **universal Gravitational constant**. It is a fundamental constant of nature, and its value can be determined experimentally. In SI system of units G = 6.67 x 10^{-11} N m^2 kg^{-2}

Points to ponder

Newton himself acknowledged that, despite deducing the equation for the magnitude of gravitational force, he remained uncertain about what gravity truly is. He could describe its effects but not its underlying nature.

In many ways, gravity remained as enigmatic after Newton as it was before him. Questions persisted: Why does gravity exhibit the behaviour it does? How does this force traverse the vacuum of space to connect two masses? Gravity, alongside other fundamental forces, presented itself as an abstract, almost incomprehensible concept that deeply intrigued Albert Einstein, leading him to formulate his General Theory of Relativity.

It's worth noting some additional aspects regarding the force law mentioned above. This expression accurately describes the relationship between two objects when their sizes are significantly smaller than the distance separating them, further it's an approximation unless the masses have a symmetric distribution.

References and Acknowledgements

1. William Stukeley(1687-1785) Memoirs of Sir Issac Newton's life(1752) pages19-20. Published by Taylor and Francis, London(1936)
https://wwwb.newtonproject.ox.ac.uk/view/texts/normalized/OTHE00001

2. Projectile motion physics libretext.org.

3. Google images

4. University Physics Ronald Lane Reese, Brooks/Cole Publishing Company, International Thomson Publishing Company 1998

Newton's Law of Gravitation: The Universal Force that Shapes the Cosmos

"I can calculate the motion of heavenly bodies, but not the madness of people." - **Sir Isaac Newton** (This quote by Newton reflects his humility about his extraordinary scientific achievements, including the law of gravitation.)

"The falling apple was not so extraordinary. It was the realization that the moon is falling too." - **Unknown**

"Every mass attracts every other mass through the force of gravity. It's the universal glue that holds the universe together." - **Neil deGrasse Tyson**

"Newton's law of universal gravitation is not a prescription for what the gravity force should be but a description of what the force is." - **Brian Greene**

THE LONG ROAD TO GRAVITATIONAL WAVES – CONCEPT TO DETECTION AND CONSEQUENCES

H. R. Madhusudan
Assistant Director, Jawaharlal Nehru Planetarium
Chowdaiah Road, Bengaluru

February 11, 2016, A Press Conference at Washington; David Reitze, the Executive Director and research professor at LIGO **(L**aser **I**nterferometer **G**ravitational **O**bservatory), Caltech, walked up to the podium. He alternated his gaze between an animation on the computer screen and the press corps. Rai Weiss was about to announce something that every physicist in general and general relativist in particular, longed to hear. Weiss announced, '*Ladies and Gentlemen, we have detected Gravitational Waves. We did it!*' The hundred years wait was over. Albert Einstein, the originator of General Theory of Relativity (GTR), was, again, riding the crest of a 'wave'. And, why not! After all, he had predicted it …exactly a century ago. Einstein's paper, published in 1916 and barely a few months after laying the foundation for GTR, remarkably predicted Gravitational Waves (GWs) or '*ripples in the fabric of spacetime*' in the popular jargon. Surprisingly, Einstein himself wondered if GWs were just mathematical fallout of GTR or if they were for real.

General relativists continued to debate about the 'reality' of GWs for four decades. A conference held in 1957 convinced many that the GWs are real and could be detected. Another two decades went by. Experimenters, notably, Joseph Weber, tried hard to build detectors that could intercept and record GWs from space, but in vain. Laser Interferometer Gravitational Observatory (LIGO) was established in 1980s. It underwent several modifications in its design over a period of 35 years. The result – the history-making announcement by Weiss on February 11!
It took several centuries for a Newton to appear and come up with a law of gravity. It took another 250 years for an Einstein to realize the necessity for a different theory of gravitation – the GTR. It took only a few months from for him to predict GWs. It took a century of combined efforts of hundreds of scientists and engineers from various disciplines spread across the world to solve Einstein's *highly interesting problem*. Here is a brief account of the progress of human thought about gravity and GW.

Newton's theory of gravitation (NTG), announced in the seventeenth century, satisfactorily explained the motion on macroscopic scale of *all* celestial bodies and also the falling bodies on the Earth. NTG, coupled with his three laws of motions, was used to describe all motions. They worked very well. Tides, positions of planets, satellites or any object could precisely be calculated and predicted using these laws over the next two and a half centuries. Combination of the laws of motion and gravitation implied that gravitational force between objects separated by *any* distance would be transmitted *instantaneously*. Gravitational force was an *'action at a distance'*. This way gravitational force would consistently behave with the way other forces such as magnetic and mechanical forces behaved. In this way, a wide range of terrestrial and astronomical phenomena came to be neatly understood. Newton's theory agreed very well with the observed celestial bodies. When new planets and comets were discovered, the theory worked equally well. The discovery of Neptune was a major triumph for NTG. Applying his theory, Newton remarkably demonstrated that the trajectory of an object moving under the gravitational influence had to be one of the four shapes – a circle, an ellipse, a hyperbola and a parabola! This great reduction was a high point in theoretical physics. Unsurprisingly, NTG held sway for a very long time. The rigour of Newton's work is amply reflected in Einstein's tribute to Newton, *'You found the only way which, in your age, was just about possible for a man of highest thought and creative power'*.

All was well with NTG until Einstein, while working on his theory of relativity between 1907 and 1915, arrived at a very important conclusion that gravity and acceleration are equivalent and also that gravity curves spacetime! This is the foundational principle of GTR. An understanding of the gravity in conjunction with relativity brought in very interesting differences between Newton's and Einstein's theories of gravity. With that came the possibility of new phenomena existing in nature that could not have been expected or guessed. The notion of gravity as a force between masses was replaced with what it does to spacetime! Not only that; while according to NTG exchange of forces was instantaneous, GTR demanded a time delay in communicating the changes in spacetime.

Was Newton's theory, then, wrongly worshipped for two and a half centuries? Not quite. Einstein's GTR could explain everything the same way that Newton's theory did for objects moving slowly in weak gravitational fields. Often, we come across more than one theory that explain and account for a set of phenomena. How, then, do we decide which of the two is a better one? One yardstick is explaining with the help of one theory some minor, second order effects, but not by the other. In this context, it was the precession of the perihelion of Mercury which results from the gravitational influence of various sources. NTG could account for a whopping 5557 arc seconds per century. The unaccountable 43 arc seconds per century, a seemingly small one, could precisely be accounted *only* by GTR! This clearly established that GTR was not just another theory '*to save appearances*. The triumph of his theory in its first outing left Einstein with *'joyous excitement for a few days'*. Newton built his non-relativistic theory of gravitation from observational data concerning the motion of the moon. He had 'something' to immediately verify. Tycho Brahe's data on planets and comets led to the formulation of three laws of planetary motion by Johannes Kepler. These laws could be independently recovered from NTG. On the other hand, it was plain intuition, which led Einstein to the theory that a complete description of gravity must include relativity. Major differences in the description of gravity in these two theories arise from this feature.

Einstein suggested two more astronomical tests that could be carried out to verify GTR. One was that light travelling in the vicinity of strong gravitational fields must show a red shift in its spectrum. This is *not* the same as the Doppler red shift, which is due to the motion of the source. And the second was the bending of light when it passes close to massive objects such as the sun. *It is highly doubtful, if anyone would have come up with an experiment to observe these two phenomena in the absence of a theoretical prediction by GTR.* Observations were made and the GTR was verified again! This is why Einstein was fond of saying, "**…***on principle, it is quite wrong to try founding a theory on observable magnitudes alone. In reality, the very opposite happens. It is the theory that decides what we can observe*"**.**

Indeed, Einstein seriously doubted the *real* existence of GWs though all relativistic theories of gravitation had to include GWs. Masses that accelerate by virtue of their spin or by their orbital motion bring about corresponding changes in the curvature of spacetime around them. These changes travel away from the source mass in all directions. Spacetime curvature is a consequence of relativity, and GWs are disturbances in spacetime. Einstein showed that GWs have a finite speed and they move at the speed of light. That is, changes in gravitational field at one point will be conveyed to another point only *after some time*! So, Newton's action-at-a-distance fails when we invoke relativity to describe gravity.

By their very nature, GWs, produced by objects that are several times the mass of the Sun and orbiting with small periods of revolution, are very weak. That is, the efficiency with which mechanical energy of an object is converted to GW is extremely low. The strength of GW wanes with distance making them very difficult, almost impossible, to get detected. If something did not lose energy or momentum to another body, then there is *no way* to detect it. This was the fundamental problem involved in detecting neutrinos. Their weakness, however, is also their strength. They can travel large stretches of spacetime without being absorbed or scattered appreciably by the intervening objects such as stars, their clusters and galaxies. However, do objects several times the mass of the sun exist? Today we know a number of them – Neutron stars (NS), pulsars and Black Holes (BH). During Einstein's age, these were not known to exist. Interestingly, Einstein also doubted BH, again a product of GTR. BHs were too bizarre an entity to be believed. Therefore, it is but natural that Einstein and his contemporaries doubted the existence of GWs.

The Chapel Hill Conference, held in 1957, debated about the physical reality of GW. Felix Pirani clearly demonstrated that relative accelerations caused by GW in the particles were measurable, meaning detectable. This demonstration motivated some prominent physicists of the time, such as Hermann Bondi, Richard Feynman and Joseph Weber to pursue Pirani's modern thinking about GW (Pirani, unfortunately, lived short of two months to hear the great news about GW detection by LIGO. He passed away on 31 December 2015!). Weber even designed the first Bar Detector in which GW impinging on massive aluminium cylinders would set the cylinders in vibration at their natural frequency. A small change in the length of the cylinders due to GW would cause Piezo-crystals to produce a voltage. But, GWs are so weak that the displacement of the order of 10^{-16} m could not have produced measurable voltage. It was a very good experiment in principle. His efforts to detect GW in this manner were not successful – not successful only if the end-result of the experiment is considered. It was, however, highly successful in attracting experimenters to this new venture of detecting GW through terrestrial experiments.

Russell Hulse and Joseph Taylor discovered in 1974 a binary system of a pulsar and a neutron star orbiting about a common centre. The pulsar emits radio waves in our direction at highly precise intervals of time. It is a high precision clock, if you like. Astronomers have been measuring the orbital period of this pulsar for nearly four decades now. What they have found out is that the orbital period is systematically reducing. Now, this can happen only if the pulsar is losing energy. Applying GTR to this system, the amount of energy lost per orbit was calculated. The observed data precisely matched the theoretically calculated amount of energy carried away by GW! This is only a circumstantial evidence for the existence of GW. So, GW could be real. The GTR turned out to be acceptable again about its prediction. For their work, Hulse and Taylor were awarded the Nobel Prize in Physics in 1993. Since the discovery of Hulse-Taylor Pulsar, several other binary pulsar systems have been studied and similar calculations have led to similar inference about GW.

A direct detection of GW was still elusive; understandably so. GW affects very little. What kind of a measuring system would allow us to detect a change in length, as small as the nuclear diameter, brought about by GW? Interference of light waves was suggested in the 1970s as a means to measure the small displacement that a GW would bring in the detector. That appeared to be the best way. Albert Michelson, a highly skilled experimenter, had employed this method in the 1890s to carry out precise measurement of the speed of light. The method has come to be known as interferometry. His experiments clearly showed the speed of light to be nearly three-lakh kilometer per second. More important was the inference that vector addition of velocities does not apply to light. That is, the speed of light is independent of the motion of the source or the measuring instrument or both. This result strongly supported the special theory of relativity that Einstein developed and into which gravity was embedded later to give rise to the GTR. As we shall see, interferometry once again played a key role in Einstein's work.

The essence of interferometry is that light from a single source is split to two directions, and they traverse a known distance before they are reflected and then they are allowed to recombine or interfere with one another. The interference shows up as regions of different intensity (brightness) - illuminated and dark regions. This is a typical property of light wave. Waves of all kinds, without an exception, demonstrate interference. The beauty of this method is that the intensity distribution of a wave of certain wavelength solely depends on the distance travelled up to the point of interference provided the speed is unaltered during the travel time. Alternately, if the distances are rigidly fixed, the intensity distribution of the wave solely depends on the speed of the wave. More important is the fact that, *the change in the intensity distribution for a wave travelling at a constant speed can be brought about by changing distances by a fraction of the wavelength*. This is *the key idea* that went into the detection of GW recently. One of the advanced LIGOs is situated at Hanford in the US. It has two arms in perpendicular directions. Each arm is 4 km in length. Light from a LASER source travels through each of these arms, get reflected by mirrors placed at the far end of each arm and finally interfere. The arm lengths and the position of the detector are so chosen as to render the interfering light to cause a dark region. As long as the length of at least one of the arms is not altered, the 'dark' persists. As GW produced by some mechanism travels through the Earth, the two arms of the LIGO detector would stretch alternately in perpendicular directions but not simultaneously. This results in a slight change in the length of one of the arms at a time, by about the size of atomic nuclei. This is sufficient to slightly illuminate the 'dark' region. Some light is now seen where there was none earlier. If both arms stretch or shrink by the same amount at the same time, there would be no change in the brightness of light. Thankfully, the differential effect in the alternate stretching of the two arms is due to a property of GW itself - its quadrupole nature. Thus, the principle of Michelson's interferometry is tailor-made to detect the GW based on this property! This is, really, a fortunate coincidence.

Setting up LIGO draws huge resource – financial and human. Establishing one such is a formidable task. Why, then, were two of them set up and why were they about 3000 km apart? It is important to have two detection systems especially when you seek to detect signals and you do not have control over the time of emission of the signal or the source. In other words, where you have no control over the source to produce signals at your call, having more than one detector helps. The reason is; detection by a single detector does not guarantee that it came from the kind of source that we want to study. It could be a spurious signal that mimics, for some reason, the signal that is of our interest. 'Coincident' detection is looked for to doubly ensure that the signal, indeed, came from a certain kind of source and that the signal is not an artefact. If two detectors detected the *very same* signal, the chances are that the signal is not an artefact. This 'coincident' method is very common in particle physics – especially in the detection of cosmic rays. So, two LIGO set-ups are justified. But, why 3000 km apart? Well, there is nothing sacred about 3000 km except that this is an appreciable separation. If the two detectors are close-by, both may be responding to the locally generated spurious signal. With a vast separation between the detectors, the chances of 'local' spurious signal being detected by both are extremely small. In the present case it led to the confirmation of the GW, both detectors detected the *very same* signal. Since the GW takes a finite time to traverse from one detector to the other, we would see the same signal about 10 milliseconds apart. This is the time taken by GW to cover a distance of 3000 km, travelling at the speed of light. LIGO detectors, at Livingston and Hanford, detected the signal with a time difference of 7 milliseconds due to the angle between the two detectors and the source. The GTR had predicted the speed of the GW to be precisely equal to that of the speed of light. With the help of 'coincident' detection, this property of GW was beautifully verified. As more and more LIGO-like detectors are set up around the world, the larger number of coincidences in the detected signals would increase our confidence level in believing them to be that of a GW. The coincident detection has another advantage. The time delay recorded in three or more detectors will enable us to literally pin-point the direction of the source of GW.

What does a LIGO detector actually detect? As the GW sweeps past the LIGO set up, the arm stretches and squeezes with a periodicity that is in step with the frequency of the GW. What decides the frequency of a GW? It is the orbital frequency with which two NSs or BHs or a NS-BH pair that produced it rotate about their common centre of mass. Or it can be due to the perturbations caused as a BH or an NS is formed in a supernova implosion. The perturbations persist as long as the BH / NS is asymmetric. When it becomes spherically symmetric, the perturbations completely die out and so will the GW associated with it. The GTR predicted that a binary system that produced a GW must lose energy. Production of GW needs energy just as we need energy to produce sound or light waves. Consequently, the size of the orbit diminishes. This results in the constituents of the binary system revolving more rapidly, thereby producing the GWs of increased frequency. Finally, the masses of the binary system coalesce into one – a merger. The coalescence is followed up by the perturbations as the final, merged BH graduates from an asymmetrical to a symmetrical one. The perturbation period is very small – less than a second. Once the merger is over, the GW ceases to be formed by this system. It has a signature pattern that indicates the nature of two objects that have merged. In the case of the merger of two BHs, which sparked the history-making observation announced on February 11, 2016, about 65 solar masses merged into a single BH of 63 solar masses. The missing 2 solar masses were entirely converted into GW energy in accordance the famous Einstein's equation: $E = mc^2$.

The formation of a merged BH was signalled by a characteristic wave pattern known as Quasi Normal Mode (QNM). The QNM is called' ringing down' these days because the QNM resembles the wave pattern of the dying sound of a bell that is struck once. The frequency of the sound remains the same but the loudness diminishes with time much like a damped oscillator. Unlike a bell that can be repeatedly struck and the resultant dying sound can be studied in a laboratory, the QNM of one BH is produced only once. The QNM is observed for a very short interval of time occasioned by the formation of a BH. After a BH is formed, its existence can only be inferred from the behavior of masses in its vicinity.

How do we know that this, indeed, is the pattern? Well, this was theoretically worked out and predicted way back in a paper published in Nature in 1970 by C V Vishveshwara. LIGO scientists matched the signal pattern that was theoretically deduced from what LIGO had recorded. The match was impeccable. CVV's work itself was based on GTR. So, the pattern matching unequivocally tells that GTR must be acceptable and secondly, it unambiguously establishes, in the process, that binary BHs do exist. This was the very first instance of directly 'observing' a binary BH. We had only circumstantial evidence for the existence of both GW and BH. In one stroke of observation, the reality of both was firmly established. Ironically, Albert Einstein did not believe in the existence of either of these.

BH can also be formed when the core of massive stars collapses under the action of gravity. The moment BH is formed, its characteristic QNM would be detected here. The GW, unimpeded by anything from the region of collapsing core to the detector on the Earth, would reach us hours before light from the supernova reaches us. Light from the core, would be absorbed and reemitted all the way from the core to the outer envelope of the dying star and from thereon to us. This causes a delay between the arrival of GW and that of light originating at the same time and the same space. Future astronomers would use the information from GW to train their telescopes precisely in the direction of the supernova and study the light coming from it right from the beginning of the end of a massive star.

All these centuries we relied upon light – a manifestation of gravitational influence – coming from celestial bodies to understand everything about them. Now we can study them, at least some of them, through gravity itself.

GWs carry important information such as mass that created it, mechanism by which it was created – whether by implosions of massive stars or by merging - and the distance from the source. All these are extremely useful. Ever since we started observing the heavens, we have always used light as a messenger and have learnt to decode rich information embedded in it. In recent times we have learnt to detect neutrinos coming from stellar cores. Both neutrinos and light are manifestations (interpreters) of gravity. We have successfully learnt to directly read gravity without an interpreter. As we learn this new language, it will surely usher in a new wave in astronomy – a wave, perhaps, not anticipated by Einstein himself!

The Journey to Gravitational Waves: A Century of Theory, Experiment, and Innovation

"We had to wait a hundred years for the technology to catch up and finally find the 'chirp' of two black holes colliding." - **Janna Levin**

"Gravitational waves are a testimony to human ingenuity and determination. They required a century of theorizing, a half-century of experimentation, and a decade of technological development." - **Kip Thorne**

"Gravitational waves are ripples in the fabric of spacetime, and their detection is a triumph of human curiosity and innovation." - **LIGO Collaboration**

"The quest for gravitational waves was a monumental scientific journey that united theory, experiment, and technology in the search for the universe's deepest secrets." - **Rainer Weiss**

"Gravitational waves teach us not only about the cosmos but also about our human capacity to explore the universe's hidden mysteries." - **Barry C. Barish**

SCIENCE AND SPIRITUALITY: LOOKING FOR A CONFLUENCE OR AN INFLUENCE?

S. K. Arun Murthi & M. R. Nandan

Between science and religion, there is no man's land. This no man's land belongs to philosophy.

- **Bertrand Russell, History of Western Philosophy**

Introduction

Let us clarify that we have attempted to separate science from what is not science only at elementary level and secondly, the thrust is on what is called pure science only. Applied sciences, like medicine and technology, fall completely outside the limits of this paper; so also, mathematics and astronomy.

A few decades ago, a philosopher by name Ernest Nagel[1] ridiculed attempts by not-so-well-educated Americans who used phrases like scientific haircut, scientific astrology, etc. This obnoxious trend has caught up with us now. Of late, there has been a growing tendency among scholars in India to promote the theory that science, as we understand it today, flourished in ancient India. What is surprising and shocking is the tenor of their claim. It is not just a theory, but according to them it is an irrevocable matter of factual statement. Some of them go to the extent of claiming that modern theories like quantum mechanics, theory of relativity, etc., were all founded by seers. Recently, the Maharaja Sayajirao University at Baroda made claims to this effect by attributing the discoveries of modern science to some of these sages[2]. This claim on the part of the university could have secured sort of stamp of authority. However, it was not to be and that is our fortune! This growing tendency is a recent phenomenon. Why is this misplaced and mistaken thinking gaining popularity?

Status of Science

It cannot be denied that science is held in very high esteem by all of us. There are two reasons for this particular widespread perception. First, science has brought to society unimaginable benefits through technology derived from it. Therefore, science acquired certain prestige. Second, science is seen to be the finest expression of human intellect which is always at its best. Admittedly, we think that respectability is acquired when we associate our study with science; a blatantly mistaken perception, but this is an element of human psychology. With respectability comes acceptability, another fallacious thinking; hence the urge to claim that ancient Indian texts are nothing but works of science. Let us examine whether they deserve this place of pride (or still a a higher place?). Let us remember that we should not be blindly carried away by any emotional appeal. How can it be done?

A comparison

A simile will help us to understand the present scenario. Suppose that I want to know whether Mr. Kapil Dev is a fast bowler. One way is to observe how he bowls and also observe the way some other bowler, say, Mr. Anil Kumble bowls and then compare their style of bowling. Now one question will prop up in the mind of a cricket-illiterate. He may ask; how do you decide whether Mr. Kapil Dev's action or Mr. Anil Kumble's action results in fast bowling? We make a list of the characteristics of fast bowling to answer this question; the length of run-up, particular style of movement of arm, minimum speed (or velocity?) at which the ball reaches the other end of the pitch, and so on. There is no escape from this exercise. We have to regard him as a fast bowler if and only if we discover that the action of Kapil Dev satisfies all these characteristics. However, if we discover that the action of the bowler satisfies not even one characteristic, then we have to conclude that the concerned bowler is not a fast bowler, example Kumble. After all, it is not the case that only a fast bowler can win the match. Nor does he stand head and shoulders above all others. Then why should we give so much of importance to him? Let us grant importance to him the extent to which he deserves.

So cricket or fast bowler is replaced by science. What applies to fast bowler applies to science too. We will assert that the characteristics of science, as in the case of fast bowling, are not decided by one or two persons - and ought not to be decided - though they are celebrities. These are the characteristics, which are universally and conventionally accepted. It is not difficult to guess what we are required to do now; search for the characteristics of science, which are conventionally accepted. Suppose that we succeed in getting and fixing those characteristics of science. Then and then only can we identify science and separate science from pseudo - science. This is an attempt to get the definition of science. This exercise also helps us to discover what science is not. At this point, one may come out with an interesting and an extravagant suggestion; why should we not alter the definition of fast bowling itself to suit our idea of fast bowling? It is a very good move. But we should know that we are not at liberty to alter what everyone has accepted just because it satisfies our ego or whim and fancy. Neither science nor cricket (read fast bowling) is a private enterprise. It is a public enterprise. Therefore no one has any right to arbitrarily alter - with or without any ulterior motive or motives - the characteristics of science. We can alter only if there are good reasons for doing so. So the thrust of this article is on the aim and characteristics of science. No one will object to the conclusion that anyone who wants to be a scientist ought or try to know what science is all about just as a person should know what music is if he or she wants to become a musician. Now we are on the threshold of understanding what science is and what science is not.

The Etymology or Origin of Science

The word 'science' is derived from the Latin word, *scientia*, which means knowledge. It entered the English language through French around 1600 C. E. where also it meant knowledge. And the word 'scientist' was introduced by another philosopher, William Whewell[3] in 1834 in his writing for the journal, Quarterly Review. The term 'scientist', therefore, is barely 189 years old term. This is the beginning of science as we are familiar with.

Initially, it meant a systematic and demonstrative knowledge. Demonstration means proving in geometric sense and that is what is called logical reasoning. Francis Bacon argued that observation and experiment also are required to acquire scientific knowledge. Subsequently, these two interpretations were amalgamated. Scientific knowledge, therefore, got a new twist. Over a period of time, the meaning of science underwent complete change. A different concept of science emerged at this point of time. This shift to a different meaning of the word had to take place as there was no concept exclusively available to identify this specific nature of activity as an independent discipline. The acceptance of the Methods of physical sciences in terms of observation, experiment and more importantly, measurement and calculation became the criteria to demarcate science from pseudo-science. Observation as an accepted method of science involves ordinary sense-experience, aided and extended by instruments, and undoubtedly not any extrasensory experience or meditative skills. Let us recall that science that all of us studied in the past and are still studying and what our progeny will study is based on senses and reasoning and nothing else.

The Concept of Science

Science has some specific features and identifying these specific features means to form a clear idea of science. This idea of science gives us the basic grammar or structure of scientific language and it is all about theories and laws of physical world which are derived or derivable from observation and experiment. However, the question is; is it possible or plausible to extract and consolidate different competing positions about the requirements of science with just one concept of science or do we require different concepts of science for different requirements? This issue can best be examined with the help of an anecdote drawn from court proceedings in the far-off USA.

As we said in the very beginning, it is not the case that such misuse and abuse of the label of science has been happening in India only. Something similar happened in the West also; it is something we imported (and we are adept at aping the West when and where we should not). William Overton[4] had to deliver his verdict in a case that came up before him on this issue. He had to decide whether or not creation- science is really a science. The verdict in this case is significant and an eye-opener in the light of the present debate and also it comes in handy to take head-on another question; why are some scholars in India are misled on this count and are misleading others as well? In the first place, why did this barren issue reach the court? The story is quite interesting. The creation-science *vs*. evolutionary science debate is the one which the USA had to grapple with when some of the states in the USA proposed a law which stipulated that schools ought to give equal priority to evolution-science and creation-science as far as teaching was concerned. The Book I of The Genesis of The Holy Bible gives an account of Creation. This account mysteriously became creation-science overnight and the supporters of this view, surprisingly, claimed scientific status to the narrative given in The Bible and denied any religious content in that account. These people took this dangerous path because the constitution of the USA prohibits the teaching of religious content in public. So the best way to introduce Biblical thought was to term it as science and the supporters of creation-science claimed that it is no less a science than the theory of evolution. There were protests from scientists and others challenging the scientific label being pasted on something that was religious in content. Finally, the case came up before the said court where the judge had to decide whether or not creation-science was really a science. What are interesting, and also important, are the criteria he considered for deciding the case and then his attitude. The criteria clearly tell you what the conception of science is. Scientific knowledge, according to this judgment, ought to have the following characteristics:

a) It is guided by natural law.
(b) It has to be explanatory by reference to natural law.
(c) It is testable against the empirical[5] world.
(d) Its conclusions are tentative, i.e., are not necessarily the final words.
(e) It is falsifiable, i.e., it can be disproved.

These characteristics need some explanation. A natural law is discovered. It is not invented. Nor is it created. It means that it is already there. No one knows how it came to be there. It is not the job of the scientist to know how it came to be. His task is only to know or try to know what it is and use it as a tool to explain natural phenomena and thereby find solution to the problem. Scientific study does not mean just listing or collecting. It is something very different. First, it begins with recognising a problem which gives rise to curiosity and curiosity propels further study. Second, it consists of a very careful and judicious examination of law. Such an examination of law includes a satisfactory explanation or explanations of phenomena. All these features in some sense or another other capture the empirical nature of science and the importance of observation and experimentation. There is an element of tentativeness in scientific theories and, therefore, any subsequent test can contradict a general law, which needs to be tested against the world of our normal sense experience, not any extra-sensory world. It only means that all scientific laws are testable. Before the judge could arrive at these criteria, he summoned several practising scientists and philosophers (neither pseudo–scientists nor pseudo - philosophers) to the witness box. Based on these criteria, the judge ruled that creation science is not a science.

This is how we should decide whether a certain discipline is a science or not. Neither breast-beating nor emotional appeal is the proper route. Application of reason alone is the proper route. We have a lesson to learn from this judgment. We must come out with sensible or examinable reasons to accept or to reject any explanation. It also means that we must have good reasons to alter well-established theory. The only sensible reason we can think of is usefulness. Usefulness deserves to be understood in two different senses; progress in our understanding of the world which marks the growth of our knowledge and second, improvement in our lifestyle. At least one of them must be satisfied which alone can justify our decision to alter the concept of science. Our decision should not be arbitrary. Further, it also means that one or two persons or groups, who are not seriously doing science, should not be allowed to dictate what science is when they cannot give any satisfactory reason. Being a societal enterprise, it has, over a long interval, built its own tradition - a healthy tradition, and tradition is different from orthodoxy. This is what scientists scrupulously followed in the past, is scrupulously following presently and will be scrupulously following in future too.
An established view of science, therefore, must be safeguarded against the vandalization of science. However, it is open to critical analysis. Debate must be objective in the sense that no one thrusts his or her view on others. Neither force nor persuasion makes sense. Only rationality, being credited with a definitive role to play, is the guiding force. In this sense and in this sense alone can we say that science is objective and testable and therefore rational?

Science understood in this sense accomplishes the much-desired aim; advancement of knowledge – knowledge of the physical world and all that is found in it. The betterment of society, in turn, follows the advancement of knowledge. This is the singular aim of science. This is real progress.

This analysis will bring us to a very interesting phase; this being the case, how are some highly educated and well-informed people convinced that science in the sense in which we have so far discussed, flourished in the not-so-distant past and why do some even go to the extent of claiming that it flourished even in distant past? We point out one of the reasons. Not many are aware of elementary fact that science evolved over a long period the way humans evolved. Just as human was not created science too was not created. Undoubtedly, primitive man or caveman, as is popularly known, is a man just as we are. Yet we admit that there is qualitative difference between primitive and the so-called modern man. Likewise, there is a vast difference between primitive science and modern science. Though the difference is in degree, but not in kind, the difference is enormous. Despite this difference we lose sight of this elemental truth. There is not only history of civilization but also history of science. It will be a costly omission if we miss the latter.

Phases of civilisation form the locus of history; pre-historic age, ancient age, so on. Extend these phases to science. Corresponding to different phases of civilisation, we have the age of non-science or pre-science, the age of primitive science and the age of experimental science. The votaries of ancient India's contribution to science point to pre-science. After making this mismatch, they equate with contemporary science. It was at this point of time that religion and mythology established their grip over the society. Mythology and religion did play a crucial role in shaping primitive science and they became sort of springboard for science to take off. This is definitely undeniable. Science is the product of a certain milieu. It is unrealistic to expect science to evolve without being influenced by the environment. Indeed, science of this age was only speculative with no theoretical base. How did mythology and religion originate? We do not believe that there is any convincing reply to this question and it is not the job of the scientist to search for the answer either.

Even in the absence of experimental inquiry, something was happening. Our ancestors looked around the world. They could record what they looked and this went on for several generations. For us, strangely, what all they recorded appear to be scientific doctrines. In their enthusiasm to showcase the achievements of their ancestors they lose sight of the fact that contrary to their illusion, no advanced science can come into existence overnight.

Steven Weinberg has beautifully brought out this crucial difference in his work, 'dreams of a final theory'. 'As an undergraduate student of philosophy, I felt some pain at hearing Hellenic philosophers like Thales or Democritus called physicists…but, when we came to…. Archimedes…I felt at home'[6]. No further discussion is required.

Against this background, the ancient texts of Indian (and also Ancient Greek) origin fail the test. There are, obviously, two possible decisions. First, give up any attempt to regard them as science in contemporary sense, the sense in which we use the term. Second, alter the very meaning of science to accommodate the said texts. First alternative is impersonal and without any prejudice whereas second alternative is an example for unscientific and irrational posture and at times for use of illegitimate authority. Science is democratic. Use of force or authority is anything but scientific.

Science and Rationality

Rationality is an essential element of science whereas passion (or frenzy?) is an essential element of religion. There is no religion in science and there is no science in religion. Contrary to what many rationalists of today argue, it does not necessarily mean arguing against the existence of the God because a person who believes in the existence god also can be as much rational as his opponent. It is s state of mind which anyone may cultivate or may fail to cultivate irrespective of his belief-system. Rationality, as different from common understanding of the term, is not provocative at all though some people have made it provocative. But this is not the case with religion in general which is driven by passion. We have seen bloodshed in all religious groups at different points of time all over the world. Violence, physical or psychological, is foreign to science.

Once Bertrand Russell, the famous philosopher – turned – mathematician, was asked a mischievous question. 'Suppose after your death, you come face to face with the God (when Russell was asked this question he was past his nineties), how would you respond?' The reply from Russell was (and 'is') quite illuminating; 'well, I would say you (God) did not provide much evidence'. Actually, one can go further and farther than Russell and say, 'not only was there any evidence for your existence but also there was evidence to the contrary'. The profundity of Russell's response lies in saying that one is entitled to accept something if and only if he has sufficient evidences. What is significant here is that there are (at least were) scientists and philosophers who hold opposite position on the existence of God without allowing any acrimonious debate. These are the defining characteristics of scientists and philosophers. And this is the difference between rationality and passion too. Science and rationality regulate our emotions and passions. This is not the case with religion. In the latter, unintellectualized emotion has the tendency and potential to degenerate into a dangerous force leading to unwarranted violence. This had happened in the past and is happening now within religious groups and between supporters and enemies of religion. This is something unheard of within the realm of hard-core science. Science and religion are different enterprises for these reasons.

Conclusion

The road with roses did not greet the growth of science in Europe. History tells us that religion trespassed its limits at crucial juncture and tried to thwart the voice of science at its very beginning. The Church persecuted scientists who opposed Aristotle because the Church regarded him as an authority on all respects. Galileo was kept under house arrest till his death. Bruno was burnt alive. Despite threats to physical safety, scientists exhibited exemplary courage to fight the papacy of the Church to uphold the sanctity of science and scientific pursuit of truth. The moral of the story is that science and spirituality or religion should remain within their respective limits because they are different games. Unfortunately, this is not happening in India. If science should progress in India without any hindrance, then this should happen.

Let us return to our old and faithful companion; fast bowler. A fast bowler does not and ought not to command undue respect. He can command only what he deserves. Other players are not to be belittled. Their positions remain should remain secure. Likewise, what is so great about science which prompts us to include spirituality under science? Seers are spiritual leaders, but they are not scientists. Spirituality stood on its own legs and was a potent force to reckon even before science took its birth. Why do you underestimate its independence and status by equating it with science when most of us rightly or wrongly believe that spirituality is superior to science? If we regard spirituality as science then what I and you studied in schools and colleges or still studying can no longer be called science. You cannot have cake and eat it too. If spirituality is in, then science is out. However, you can be a scientist and also truly spiritual just as a historian can be a good Chess player as well. It only means that you have simultaneously developed two different faculties. After all spirituality is absolutely necessary at a time when science is hijacked by politicians and religious leaders and when scientific research is dictated by capitalists. Let us end up with Einstein's slightly altered famous aphorism; Science without religion (spirituality) is blind and religion (spirituality) without science is lame (within parentheses mine). If science is the fast bowler, then what is spirituality? It is anybody's guess. There is no judgemental exercise involved here.

References

1. Nagel Ernest, The Structure of Science, Routledge and Kegan Paul, London, 1961, p. 2
2. Maharaja Sayajirao University, Baroda, had made these claims in their official diary, 2017. See https://thewire.in/ 115273/maharaja-sayajirao-university-diary/, viewed on 25 April, 2017
3. Whewell was well known for his terminological assistance and also invented terms like ion, cathode and anode for Michael Faraday. See https://plato. stanford.edu/ entries/whewell/, viewed on 25 April, 2017.
4. The State of Arkansas in United States in March 1981 passed a law (Arkansas Act 590) entitled "Balanced Treatment for Creation-Science and Evolution-Science Act" that required "public schools within that state give balanced treatment to creation-science and to

evolutionscience" as far as teaching was concerned. See http://www.talkorigins.org/faqs/mclean-v-arkansas.html#n22, viewed on 25 April, 2017.

5. By 'empirical' world we mean the world which can be observed with sense organs, aided or unaided by tools. (This particular reference is strongly recommended only for those who are experienced research scholars and not for beginners.)
6. [Ross, Sydney (1964): "Scientist: The Story of a Word", Annals of Science, Vol. 18 No. 2, pp. 65-85, viewed on 25 April 2017, http://www.tandfonline.com/doi/pdf/10.1080/00033796200202722
7. Steven Weinberg, dreams of a final theory, Vintage edition, London 1993

Exploring the Cosmic Dance: Where Science and Spirituality Meet

"The most beautiful thing we can experience is the mysterious. It is the source of all true art and science." - **Albert Einstein**

"Science investigates; religion interprets. Science gives man knowledge, which is power; religion gives man wisdom, which is control." - **Martin Luther King Jr.**

"Science is not only compatible with spirituality; it is a profound source of spirituality." - **Carl Sagan**

"The most incomprehensible thing about the universe is that it is comprehensible." - **Albert Einstein**

"There is no sharp boundary line separating the reactions of the immune system from the reactions of the spirit." - **George Solomon**

"Science is a way of thinking much more than it is a body of knowledge." - **Carl Sagan**

"To know the mighty works of God, to comprehend His wisdom and majesty and power; to appreciate, in degree, the wonderful workings of His laws, surely all this must be a pleasing and acceptable mode of worship to the highest, to whom ignorance cannot be more grateful than knowledge." - **Nicolaus Copernicus**

THE NOBEL PRIZE IN PHYSICS 2023

Pierre Agostini
The Ohio State University
Columbus, USA

Ferenc Krausz
Max Planck Institute of Quantum Optics
Garching and Ludwig-Maximilians-Universität
München, Germany

Anne L'Huillier
Lund University, Sweden

for experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter

The three Nobel Laureates in Physics 2023 are being recognised for their experiments, which have given humanity new tools for exploring the world of electrons inside atoms and molecules. Pierre Agostini, Ferenc Krausz and Anne L'Huillier have demonstrated a way to create extremely short pulses of light that can be used to measure the rapid processes in which electrons move or change energy.

Fast-moving events flow into each other when perceived by humans, just like a film that consists of still images is perceived as continual movement. If we want to investigate really brief events, we need special technology. In the world of electrons, changes occur in a few tenths of an *attosecond* – an attosecond is so short that there are as many in one second as there have been seconds since the birth of the universe.

The laureates' experiments have produced pulses of light so short that they are measured in attoseconds,

In 1987, **Anne L'Huillier** discovered that many different overtones of light arose when she transmitted infrared laser light through a noble gas. Each overtone is a light wave with a given number of cycles for each cycle in the laser light. The laser light interacting with atoms in the gas causes them; it gives some electrons extra energy that is then emitted as light. Anne L'Huillier has continued to explore this phenomenon, laying the ground for subsequent breakthroughs.

In 2001, **Pierre Agostini** succeeded in producing and investigating a series of consecutive light pulses, in which each pulse lasted just 250 attoseconds. At the same time, **Ferenc Krausz** was working with another type of experiment, one that made it possible to isolate a single light pulse that lasted 650 attoseconds.

The laureates' contributions have enabled the investigation of processes that are so rapid they were previously impossible to follow.

"We can now open the door to the world of electrons. Attosecond physics allows us to understand mechanisms that are governed by electrons. The next step will be utilising them," says Eva Olsson, Chair of the Nobel Committee for Physics.

There are potential applications in many different areas. In electronics, for example, it is important to understand and control how electrons behave in a material. Attosecond pulses can also be used to identify different molecules, such as in medical diagnostics.

****

Attophysics — new tools to fathom the world of electrons | Explained