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Contents

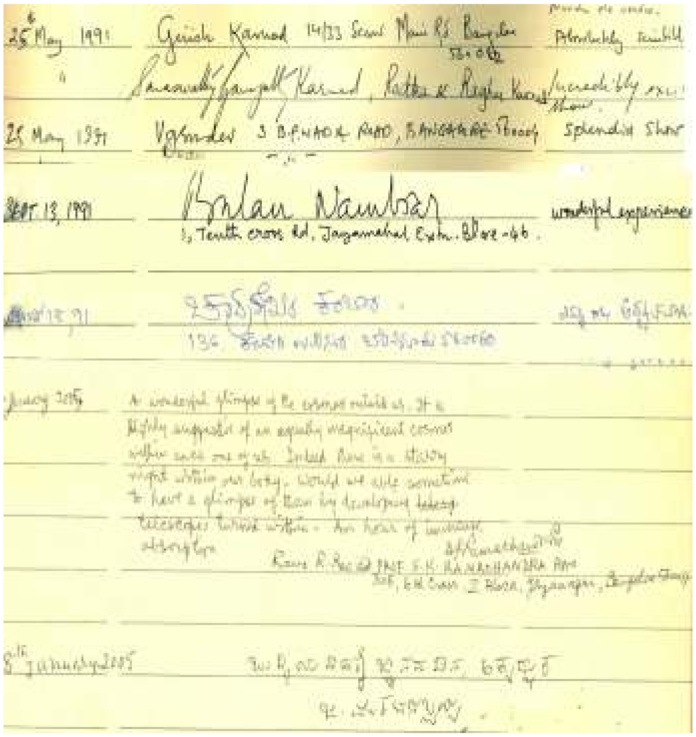
Comet Catalina

Photographed by G Chandrashekhar on 19th December 2015 from Halaguru, near Kanakapura; Stack of 9 frames of 2 minutes each plus 10 darks and 15 flats using Canon 600D, ISO800 on EQ6 mount

25 years ago -

Litterateurs and Artists at the Planetarium

Many litterateurs have visited the Planetarium; here are the impressions of eminent scholars Prof S K Ramachandra Rao, Lexicographer G Venkatasubbiah, Jnyaanpith awardees Chandrashekhara Kambara and Girish Karnad and eminent artists Vasudev and Balan Nambiar



25 May 1991 Girish Karnad

25 May 1991 Vasudev Splendid Show

Sept 13, 1991 Balan Nambiar wonderful experience
1, Tenth cross Rd, Jayamahal Extn. Blore-46.

The Literature of Science

- *S Lokanathan*

Literature conveys a sense of lasting excellence. Think of a *Kalidasa* or a Chaucer and you have a feel for the time scale. The main function may be to please rather than educate. But the two are not mutually exclusive. For many, the pleasure is from the ability of a work to stimulate our thoughts. Good Literature is participatory though different readers may not always respond the same way to a work. The enjoyment is enhanced if we attempt, not always with success, to understand the context of the author's work. This is where we have a problem with the Literature of Science. It is indeed difficult to read, say, Aristotle's writings on the laws of motion – he believed that a projectile moved in a straight line until it stopped and then fell down vertically. How could he have been so wrong? Our understanding is enriched if we try to see what the nature of Aristotle's preoccupations was and the problems he tried to solve. Works of Science may be 'dated' but our appreciation is the greater if, as a song goes, we heed the author's beckoning: "*Do You See What I See*". Here is an example from 'On the Nature of Things' by Lucretius⁽¹⁾, a Roman Poet and Philosopher at the time of Julius Caesar: "*Since I see that the chiefest members of and parts of the*

world are destroyed and begotten anew, I may be sure that for heaven and earth as well there has been a time of beginning and there will be a time of destruction". Still, the heavens and the earth continued their hallowed existence. The Persian Poet-Astronomer, Omar Khayyam was to write some 1100 years later (early 12th century) in his 'Rubaiyat' (i.e, Quatrains, four line stanzas):

And that inverted Bowl they call the Sky,
Whereunder crawling coop'd we live and die,
Lift not your hands to It for help – for It
As impotently moves as you and I.

Broadly, Science literature may be divided into the following categories: (a) Pedagogical, technical expositions, treatises and popular writings; (b) Philosophical, dealing with ontological issues, meanings of terms like Truth and Reality and questions about epistemology, the structure and methods of Science; (c) Social and Cultural aspects, the organization of Science, intra Science relations, ethics, values etc (d) History of Science, 'internal history' – the way a particular branch developed, and external history – the more difficult question of the growth of a Science in its Social and Cultural setting (e) Scientific imagination – stories of science fiction etc. I do not intend to talk about all these, rather about a few works on some of these that I have read with pleasure and profit.

It was in 1492 that Christopher Columbus made his famous voyage to the Americas in the flagship Santa Maria. Its effect on Astronomy and subsequently on Science was indirect but crucial all the same. Some fifty years on (1543), Nicolas Copernicus published the *'Revolutions of the Heavenly Spheres'*(2). Beginning with remarks that the earth and the world are spherical, he argued that *'the Sun gives us the year, the moon the months ... and each of the other five planets (*that was the number known then-SL*) follows its own cycle'*. The progress in Astronomy that this ushered in was aided greatly by the new optical instrument, the telescope, discovered soon after. (3) But the great revolution in Physical Sciences really began with Galileo's inquiries into the causes of motion. Scientists are nearly unanimous in their choice of Galileo as the founder of modern Physical Sciences. He was the first to use a telescope for astronomical studies and is often thought to be the founder of the experimental method – although the dropping of two objects of dissimilar weights from the Leaning Tower of Pisa is almost certainly an apocryphal tale. In fact the charm of Galileo was the ingenuity of his arguments using the empirical evidence available to him. The works of Galileo, *'Dialogues on the Two Chief Systems of the World'* (1632) and *'Dialogues Concerning Two New Sciences*' (1665)(4) remain two of the greatest works on Science. The first was a powerful defence of the Heliocentric system. The second is his venture into the new dynamics. The dialogues are between three interlocutors, Salviati, Sagredo and Simplicio. These, in fact, were (respectively) caricatures of Galileo himself, an intelligent common man and an unquestioning follower of the establishment respectively. Galileo is sometimes portrayed as the first consistent exponent of the experimental method and the dialogues do describe a number of experiments. But it is his ingenious use of logic aided by demonstrations, often just thought experiments, which mark his greatness.

The chief advocate of the primacy of empiricism was the Englishman, Francis Bacon, a public figure during the reigns of Elizabeth I and James I of England. He published his *'Novum Organum'*(5) - New Knowledge – compiled as a series of well over a hundred aphorisms (general truths) about acquiring knowledge. Bacon stated his main theme in a preface: "*I propose to establish progressive stages of certainty. The evidence of the sense, helped and guarded by a certain process of correction, I retain. But the mental operation which follows the act of sense I for the most part reject ...*". Bacon assumed that knowledge would emerge inductively from the evidence of the senses. The true way according to him "..*derives axioms from the senses and particulars, rising by a gradual and unbroken ascent, so that it arrives at the most general axioms last of all*". Today, most Scientists and Philosophers would reject this view. All the same this work stimulated a good deal of thinking about the methodology of Science and is an enjoyable read.

Isaac Newton, arguably the most famous name in the history of Science, was born in 1642, the year that Galileo died. An extraordinarily neurotic man, quite unwilling to publish his works until goaded to by a few of his confidants (notably the astronomer Edmund Halley), he brought out his magnum opus, *'The Principia'* around 1687(5). It was written in Latin – an English version appeared only in 1729, a couple of years after Newton died. The writings of Copernicus and Galileo, for all their brilliance and courage, reflect the caution they had to exercise before propounding their ideas lest they be accused of heresy. Copernicus dedicated his work to the Pope. Galileo was intimidated enough to retract his theses. Isaac Newton, on the other hand, enjoyed the liberty of the Puritan revolution that threw off the shackles of the established church. He prefaces his three laws of motion with a set of definitions that introduce concepts of mass and force. It is not heresy that he fears: "*I heartily beg that what I have here done may be read with forbearance; and that my labours in a subject so difficult may be examined, not with so much with a view to censure, as to remedy their effects*". His writings reflect the intensity of his preoccupations – whether in Mechanics or Optics or any other field – and rarely refer to other work, although he did make the famous remark, writing to Robert Hooke: "*If I have seen further than other men it is because I stood on the shoulders of giants*". His comment that he *'framed no hypothesis*' is confusing because his discovery of Universal Gravitation would, in today's parlance, be regarded as the greatest hypothesis! Perhaps what he meant was that he would not venture to assign a cause for the 'power of gravity'. Newton's greatest achievement was to dethrone celestial bodies from any special status. Their laws of motion are no different from those of earthly bodies. A very fine essay on 'Newton, the Man' was contributed by the famous Economist, John Maynard Keynes, in 1947 in honour of the tercentenary celebrations of Newton's birth. (6).

Newton represented a watershed in the progress of Science. It (Science) had attained autonomy and the establishment or overthrow of a theory had its own criteria. Today that faith in Science raises philosophical questions about the permanence of 'Scientific Truths' as new theories displace old ones. Consider these historic 'truths': Sadi Carnot wrote his great paper on the ideal heat engine (the Carnot cycle today) thinking that heat was a 'Caloric fluid'(6). Maxwell's electromagnetic equations were (he thought) based on the aether. So much so a modern Historian of Science, Thomas Kuhn, even suggested that an older theory, which had been of great practical use, and a newer version which had supplanted it may have no common features – he called them 'paradigms' in his famous work "*The Structure of Scientific Revolutions*"(7).

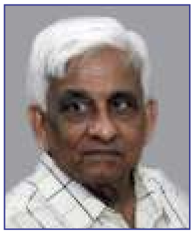
Then, what is Science all about if its theories do not have permanent status? One of the finest works on these questions is *'The Structure of Science*' (8) by Ernest Nagel, an American Philosopher of Science. Its vision is panoramic and discusses the patterns of scientific explanations in its theories and its experimental bases in physical and biological Sciences. There is a particularly illuminating discussion on *'The Reduction of Theories'*. There was a time when many believed that all of physics, if not other sciences, could be reduced to Mechanics (Newton's Corpuscular Theory of Light, for example); one of the major reasons for this faith was the great success of Statistical Mechanics not merely in understanding Thermodynamics but going even beyond its scope with success. This was soon belied by developments in electrodynamics and other fields. But if naive reductionism fails, 'unification' has remained the goal of theorists.

Indeed a measure of the progress in a Science and its sophistication is that it brings the understanding of diverse phenomena, seemingly unconnected, from fewer hypotheses. Still, there remain fascinating differences of style in the explanatory structure of Biology, for example, and Physics. A Biologist will not hesitate to offer 'goal directed' explanations such as "*the function of chlorophyll in plants is to perform photosynthesis*". Physicists are hardly likely to sympathize with this statement of Boyle's law: *'A gas at constant temperature under variable pressure adjusts its volume in order to keep the product PV constant'*! But Nagel shows that such teleological statements need not be fundamentally in conflict with statements of causal laws.

Anthropocentrism in its extreme form, the idea that the Universe is so constructed as to enable Man to fulfill his destiny, underwent a severe blow from two great scientific events. First, Copernicus, with his heliocentric theory, reduced the status of the earth to just another planet going around the Sun. And for Kepler, even the Sun was not quite at the centre of this system but at a 'focus'. But the great blow came from Charles Darwin and Alfred Wallace. They did to biology what Copernicus did to the inorganic. Darwin's great work "*The Origin of Species*" was published in 1859(9) and was the culmination of decades of systematic observation and thought. This work remains a classic. It is said that great literature flows from the portrayal of the characters of the work. But it also unfolds the character of the author. Here is an extract from the '*Origin*'. "*With respect to the lapse of time not having been sufficient since our planet was consolidated for the assumed amount of organic change, and this objection, as urged by Sir William Thompson (*now better known to physicists as Lord Kelvin-SL*), is probably one of the gravest as yet advanced, I can only say, firstly, that we do not know at what rate species change as measured by years, and secondly that many philosophers are not as yet willing to admit that we do not know enough of the constitution of the universe and of the interior of the globe to speculate with safety on its past duration. That the geological record is imperfect all will admit; but that it is imperfect to the degree required by our theory, few will be inclined to admit"*.

Perhaps I should add a few comments about the issue here. Lord Kelvin, an expert on heat, had essayed that the life of the earth was hardly likely to be more than about five hundred million years from his calculations of the cooling of the earth and he had even made snide remarks about the estimates from the lesser developed sciences. It turned out that Kelvin was wrong and the scientists from those *'lesser developed'* sciences were right - for an interesting reason. A few years later, around the early twentieth century, it was realized that radioactive matter inside the earth provided unaccounted sources of heat that Kelvin could not have known in his time. Darwin's comment that we knew little of the interior of the earth was prophetic and his confidence in his own theory was expressed with firmness and yet with grace.

Indeed the charm of the "Origin" is that it reads like one long and continuous argument. *(to be continued...)*



Prof S Lokanathan has been a source of inspiration for all our educational programs; he taught the undergraduate students which eventually transformed in to REAP.

References:

1. Lucretius lived from about 100-55 B.C; This famous work has been republished in:"Man and the Universe: THE PHILOSOPHERS OF SCIENCE" Random House, New York, 1947. This book contains extracts (& some in entirety) of famous works by Copernicus, Francis Bacon, Darwin, Eddington & Einstein among others.
2. Nicolas Copernicus was born in Poland (1473). He was educated in Law and Medicine. He devoted the last two decades of his life to the study of Mathematics and Astronomy. His great work 'De revolutionibus orbium celestium' was published in 1543 when he was on his deathbed. A portion of this translated (On the Revolutions of the Celestial Spheres) is printed in reference (1) cited above.
3. Pannekoek, A, provides an excellent coverage of the developments in “A History of Astronomy”, published by Dover Books, 1989. This book is in two parts. Part 1 traces the evolution of Astronomy into a Science from its ancient origins in various cultures ("Astronomy in the Ancient World") and part 2 describes the development of modern astronomy ("Astronomy in Revolution").
4. Galileo Galilei was born in 1564 and died in in 1642, the year Isaac Newton was born. His great work 'Dialogue Concerning the Two Great world Systems' was published in 1632. An extract from this is published in 'The World of Physics', Volume 1 (Pp 455-463). This is a set of three volumes edited by Jefferson Hane Weaver, published by Simon & Schuster, N.Y (1987). Galileo's other great work 'Dialogues Concerning Two New Sciences' was first published around 1638. The English version is available in paperback by Dover Publications, New York published in 1954.
5. Francis Bacon rose to be the Lord Chancellor under King James I. His 'Novum Organum' was published in 1620 and is reprinted in THE PHILOSOPHERS OF SCIENCE cited above. Bacon stated in his preface: "The evidence of the sense, helped and guarded by a certain process of correction, I retain". A modern view is that he severely over emphasized the role of induction; perhaps this ignores the historic role of his criticism of beliefs without empirical basis.
6. Selections from Newton's Principia and from his Optics are reprinted in 'The World of Physics', Volume 1 (Pp 480-536) of a set of three volumes edited by Jefferson Hane Weaver, published by Simon & Schuster, N.Y (1987). These contain a wide range of articles, some original papers, popular talks and articles. The essay on Newton by J.M.Keynes is reprinted in Vol I (Pp 536-547). Sadi Carnot's paper is also in this Volume (Pp725-734).
7. Thomas S. Kuhn's famous work 'The Structure of Scientific Revolutions' established his fame as a historian of Science. It was published by the University of Chicago Press in ....Among his other writings is a fine collection of essays 'The Essential Tension', published by the University of Chicago Press (1977).
8. Ernest Nagel was a Professor of Philosophy in Columbia University, N.Y. This work 'The Structure of Science' was first published by Routledge & Keegan Paul, London in It has been republished by Macmillan of India in 1984.
9. Charles Darwin lived from 1809 – 1882. His history-making 'The Origin of Species by Natural Selection' (to give its full title) was published in 1859. A selection from it is published in THE PHILOSOPHERS OF SCIENCE cited in (1) above. His other famous work "The Descent of Man" was published in 1871.

A LOOK AT THE WONDERFUL WORLD OF LIGHT- RAY AND WAVE OPTICS

-G.S. Ranganath

The UNESCO declared 2015 as the “International Year of Light and Light Based Technologies”. Under this pretext it is good to ponder about the all pervading Light and admire its wonderful world. Here we recollect a few of the remarkable discoveries in optics that are not adequately emphasized in undergraduate education. The aim is to impress upon students that Light, in its varied manifestations, is still an active fashionable area of research that is both exciting and exhilarating.

LIGHT RAYS IN A GRAVITATIONAL FIELD

Isaac Newton thought that light had weight and behaved as a stream of particles. He stated at the end of his treatise on “Opticks” that as light grazes past a gravitating mass it would be attracted towards it and thus deflected from its path. The corresponding deflection was estimated, using Newtonian mechanics, by the German physicist G. von Soldner in 1804. It turned out to be about 0.9 arc seconds for a light ray grazing the Sun. Nearly 200 years later Albert Einstein made a very similar prediction from his theory of gravitation. However, he predicted a value of 1.8 arc seconds, i.e., twice that predicted by Soldner. It is now a part of history that observations supported Einstein's prediction. Thus gravitating bodies bend light rays, just as in a lens, and can lead to image formation. Unlike in a normal optical lens here the maximum bending occurs for rays closest to the center of the gravitational lens and minimum bending occurs for light farthest from the center of it. Also, the gravitational lens has no focal point but, instead, a focal line. If a massive gravitating object is in the line of sight of the source and the observer, then the original source appears as a ring around the gravitating object. This is referred to as the Einstein Ring or Einstein-Chwolson Ring. The effect was first suggested in 1924 by the Russian physicist O. Chwolson and later worked out in detail by Einstein in 1936. If the gravitating mass is off the line-of-sight of a light source, then we get arcs or multiple images of the light source around the gravitating body.

In 1979, a pair of quasars was discovered in the neighbourhood of a radio source. They were 5 arc seconds apart and strangely had identical optical spectra. They were later established to be two images of a single quasar, by a galaxy in front of the quasar. Similarly, Einstein Rings and other possible images of stars and galaxies that are otherwise invisible have all been seen. The fig. 1 shows four images, captured by the Hubble space Telescope, of one and the same distant quasar. The images are due to the gravitational lens effect of a foreground galaxy.

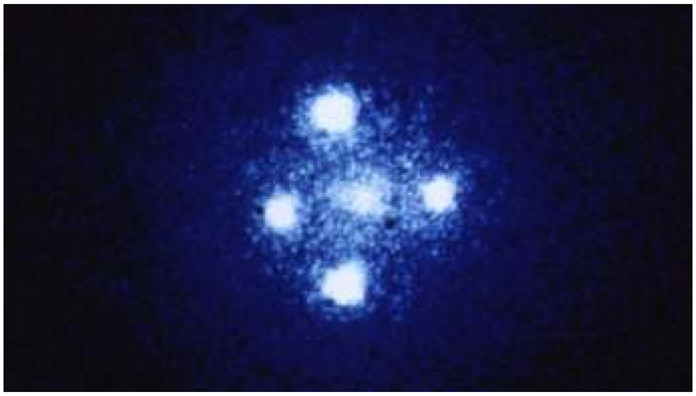


Fig.1. Gravitational Lens Effect: Formation of four images of the same distant quasar. (http://hubblesite.org/newscenter/archive/releases/1990/20/image/a/)

Observations indicate that the visible mass in the universe, like the stars and the galaxies, can account for only a small fraction of the gravitational effects seen in the universe. It was therefore proposed that the remaining large part of the mass is invisible and hence was termed Dark Matter. Dark matter is found wherever regular matter is present. Light coming from more distant stars and galaxies that passes close to a large cluster of galaxies will get bent by gravitational lens effect of the cluster. It is the dark matter in the cluster that does most of the bending of light, as it outweighs regular matter by nearly a factor of five.

LIGHT WAVES

Near field Microscopy-Seeing the Invisible

We know from ray optics that however small an object is, its image will be clear and distinct if we employ aberration free lens or system of lenses. This means that there is, in principle, no limit to optical resolution. But the German physicist Ernst Abbe showed in 1873 that the wave nature of light limits the resolution of an optical system because of the diffraction of the light waves. As a consequence, the smallest size or detail that can be clearly seen in an object turns out to be about half the wavelength of light used to see the object. Below this dimension, diffraction swamps the image and it becomes fuzzy. This is often called the diffraction limit of resolution. Very interestingly scientists have, in recent times, overcome this limitation by exploiting an altogether different form of light wave viz. Evanescent Light Wave. We shall look at the history and the physics behind such a wave.

The famous Indian scientist J.C. Bose did an ingenious experiment in 1897 with microwaves and double dielectric prisms. Microwaves entered a right-angled dielectric prism normal to one of the sides adjacent to the right angle and fell on the hypotenuse. Since it fell on the hypotenuse at an angle greater than the critical angle, it got totally internally reflected and emerged out of the other side adjacent to the right angle. Next, he brought a second right angled dielectric prism close to the first prism such that the hypotenuse of the second prism faced the hypotenuse of the first prism. When the two faces were within a certain distance, he got microwaves out from the second prism. This beautifully demonstrated that there was microwave present even in the rarer medium between the two prisms, though geometrical optics did not permit it. This can be accounted for by using the wave nature of light, wherein light waves penetrate or "tunnel out" a small distance into the rarer medium. This is a non-propagating wave. It is called the evanescent wave. The essence of this experiment is schematically shown in the Fig. 2.

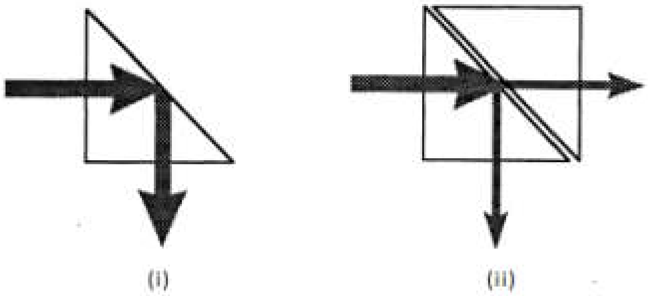


Fig.2. J. C. Bose's Experiment-(i) Total Internal Reflection (ii) Optical Tunneling.

In 1927 C.V Raman, another eminent Indian Scientist, did a similar experiment with light. Instead of a second prism, Raman brought a sharp razor-edge close to the hypotenuse of the first prism. When it was very close to the face, it started diffracting light. It was diffracting the evanescent waves. In 1908 Raman came across three papers by G. Dubern, an Indian engineer, which had been published in 1888 in Indian Engineering. These were on what the author called an "Ultra Microscope". This engineer had discovered that small optically invisible particles present on a glass plate placed below a microscope became visible when light entered the plate at an angle greater than the critical angle, from its slanted end surface. The light suffered a series of total internal reflections inside the glass plate. The particles on the glass plate were becoming visible by diffracting the evanescent wave in all directions. Since this work was published in an obscure journal, it had escaped the attention of physicists. Raman brought this work to the notice of the physicists by writing about it in the *Philosophical magazine (1909)*.

This work illustrates, in essence, the principle behind the present day near-field microscope. When a sub-wavelength structure is bathed in an evanescent optical wave, the object diffracts the evanescent wave and becomes visible. Thus though through normal optics a sub-wavelength structure is invisible, it can be seen in an evanescent wave or in near field optics. We get evanescent waves even when light emerges out of an aperture of width smaller than the wavelength of light. For example, light entering an optical fiber becomes evanescent when the fiber is tapered so that, when the light emerges out, the opening is smaller than the wavelength of light. In 1993 using this mechanism, two scientists E. Betzig and R.J. Chichester of AT and T Laboratories, USA built an evanescent wave optical microscope. They could clearly see individual molecules of size about 50 nanometers.

Non-linear Optics

Self-Focusing of Laser Light

We generally think of the refractive index of a medium for any given colour as being a constant for that medium. This is true as long as the light intensity is small. However, at high levels of intensity, the refractive index becomes intensity dependent. In such a case, the medium is said have become non-linear. In fact in most materials the refractive index increases with intensity. With the advent of lasers, the intensity effects on the refractive index became apparent. Usually the intensity across a laser beam will not be a constant. Starting from a high value at the center of the beam it gradually falls off with distance from the center. Thus generally a nonlinear medium will have a higher refractive index at the center of the laser beam than at its edges. In effect, therefore, the medium acts as a convex lens. As a consequence, the laser beam gets self-focused. Some times during self-focusing the local intensity, or equivalently the local electric field can increase to such high values that there will be an electric discharge or a spark with a bang!

Wave Mixing

In a normal (linear) medium, light waves of different colours (wavelengths) can coexist without transfer of energy between them. But strangely, in a non-linear medium the waves get mixed with energy flowing from one wave to the other. Even waves of the same wavelength or colour get mixed up. For example if we have three light waves of the same frequency or colour travelling in the same direction, we get a fourth wave travelling in the same direction. This wave will be of thrice the frequency and thus of a totally different colour. This is called the third harmonic. This wave, under favourable conditions, can even grow in intensity at the expense of the input waves. The physics of wave-mixing was developed in detail by the American physicist N. Bloembergen and his co-workers. In general by a proper mixing of light waves one can generate intense light beams in both the ultraviolet and infrared regions. By employing this technique they extended laser spectroscopy to wavelengths beyond the visible part of the spectrum. Such spectroscopic studies have immensely helped us in understanding many otherwise inaccessible molecular processes.

When an outside light wave , also called a probe wave, is incident on a nonlinear medium which already has two identical light waves travelling in opposite directions, then a fourth wave will be generated which will be counter propagating i.e. travelling exactly opposite to the probe wave. If the incident wave is convergent, the reflected fourth wave will also be equally convergent. This phenomenon is called phase conjugation. Under certain circumstances the phase conjugated wave can even be more intense than the probe wave by drawing energy from the already existing waves inside the medium. This process of four-wave mixing is depicted in the Fig. 3.

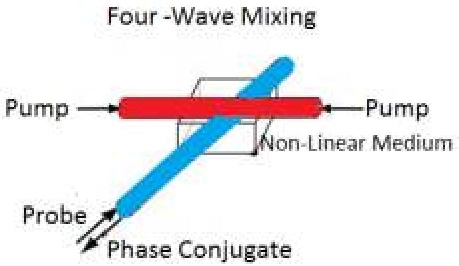


Fig.3. Four-Wave Mixing in a non-linear medium.

During Ronald Regan's presidency defense scientists in the USA even thought of making a weapon based on this effect. Light from any external object will act as a probe wave which on reaching the nonlinear medium pumped with oppositely travelling strong laser beams will generate an intense phase conjugated wave that will focus on the very same object that sent the probe wave and destroy it.

Conclusion

We considered a few beautiful examples from current research in ray and wave optics to illustrate the implications of the concepts involved. We shall look at the quantum nature of light in the next part.

G.S. Ranganath was a visiting professor at the Centre for Nano and Soft Matter Sciences, Bangalore. Formerly he was professor and dean of research at the Raman Research Institute, Bangalore. Liquid Crystals and Optics are his areas of research. He is a fellow of the Indian Academy of Sciences and the National Academy of Sciences India. He is also committed to popularizing Physics. He has been an active contributor to the various educational programs conducted by the Jawaharlal Planetarium, Bangalore. He is known for presenting science in a lucid way through popular articles in Kannada.

REAPers Speak:

Observational signatures of astrophysical black holes

- Prashanth Mohan

A large number of galaxies in the observable universe are believed to host central supermassive black holes (10^6 - 10^9 times the solar mass). They make their presence felt through a plethora of observational signatures, spanning the entire electromagnetic spectrum (radio - gamma rays) and putatively through the emission of gravitational waves. Some of these phenomena include their effects on stellar distributions and gas streams in their close proximity, leading to their interaction with the galaxy at large scales through feedback, their tidal shredding of a passing, nearby star which results in a strong ultra-violet flare, a transient event which can be captured by space based observatories such as SWIFT and possibly with ASTROSAT, our very own recently launched multi-wavelength observatory. Of particular relevance to my work is the study of active galaxies, where the supermassive black hole plays an active role in creating a conducive environment for accretion of gas and remnant stellar material in terms of an accretion disk as well as in powering highly relativistic outflows or jets. These galaxies host a very bright, persistently variable nucleus and are called active galactic nuclei (AGN). Electromagnetic flux from AGN indicates strong and persistent variability over a diverse range of time-scales ranging from a few hundred seconds in gamma rays to months and years in the optical and radio.

Variability of flux as a function of observation time (light curve) can be studied in the context of physical processes in the accretion disk or jet. Some key concerns include understanding its cause, the possibility of quasi-periodicity and relevant physical mechanisms, and distinguishing between the many theoretical models through their observationally relevant signatures. The purpose is to constrain properties of the supermassive black holes which we cannot directly infer, such as its mass and spin. We approached the problem through the timing analysis of multi-wavelength observations (using techniques such as the Fourier power spectrum and wavelet analysis) as well by constructing theoretical models which are purely geometric, involving the motion of light and particles in the strong gravity of the black hole, by using an underlying general relativistic framework. We analyzed light curves from a variety of AGN including radio loud and quiet sources including blazars (BL Lacertae objects and quasars) and Seyfert galaxies. From this, we inferred their power spectra shape, possible quasi-periodic oscillations and other relevant timescales. We then compared these results with simulated light curves and their power spectra from the theoretical models, finding that these simple geometrical models can adequately capture some key features of the observations, and in the process, allowing us to constrain the black hole properties.

After the PhD from the Indian Institute of Astrophysics (IIA) under the guidance of Prof. Arun Mangalam, Prashanth was a post-doctoral fellow at the Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital. He is currently a post-doctoral fellow at the Shanghai Astronomical Observatory (SHAO), Shanghai, China. His research interests include the study of AGN and X-ray binaries as well as radio transients including fast radio bursts (FRBs), very large baseline interferometry (VLBI) observations and large survey based science possibilities with the upcoming square kilometre array (SKA) and its precursors.

A Popular Misconception in Fluid Dynamics

-H R Madhusudan

Very early in the school education we learn that the pressure in a column of fluid varies directly as depth.

Pressure at any point is the product of the density of the liquid, acceleration due to gravity and the height of the liquid column measured between the point in question and the top surface. This comes out of the Bernoulli principle applied to a fluid at rest

This concept is used in routinely solving several problems in fluid statics. However, the idea is wrongly applied to fluid dynamics problems because of which we find a common error in many a text books – both in school and college which say that the bottom-most hole throws water to the maximum distance on the ground. The top most one, the least and intermediate holes have intermediate ranges!

Consider a cylindrical container of length one metre and open at the top. Suppose we make holes along the side of the container at 25 cm, 50 cm and 75 cm measured from the top. There is nothing sacred about these distances except that the symmetry makes our argument later easy. Let the container be completely filled with water. Now the question is: Water flowing out of which of the three holes is thrown to the maximum distance on the ground measured from the base of the container? Many textbooks do give figures similar to the one you see here.

As shown in the figure, the horizontal distance (range) covered by water is a maximum for the bottom-most hole and it is less for the middle one and least for the top most hole. At first instance nothing seems amiss. After all, pressure varies with depth and the intuitive idea is that the range varies directly as pressure. This idea is somehow ingrained in the minds of students and teachers. And, that is the source of error. Most do not take the time of flight into account. At least, that is the inference we draw from the informal interactions we have had with teachers and students. Greater the time of flight, longer will the range be. Again, the velocity of efflux is another factor that determines the range. One has to take both factors in arriving at an expression for the range covered by water. Here, we have a simple derivation of the same:

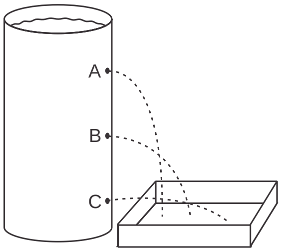


Fig 1

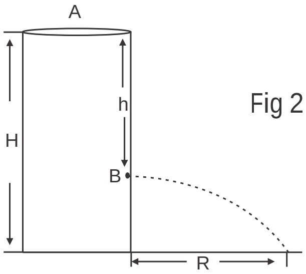


Fig 2

Suppose the cross section of the container to be large compared to the dimension of the holes. The fluid may be assumed to be at rest at the top. Alternately, we can adjust the rate of inflow of water into the pipe such that the level of the water in the pipe remains unaltered. Then, applying Bernoulli equations to the points A and B keeping in mind that at the point A, the pressure is atmospheric pressure, we get:

$$P_a + \tfrac{1}{2}\rho V_1^2 + \rho g(H-h) = P + \rho gH$$

P_a = atmospheric pressure, V_1 = velocity of efflux, ρ = density of the fluid and P = pressure of air above the liquid.

This leads to $v_1 = \sqrt{[2(P-P_a)/\rho + 2gh]}$

If the container is open to the atmosphere, then $P = P_a$

Therefore, $V_1 = \sqrt{[2gh]}$ for water falling through air of negligible drag.

This implies that for an open container, the velocity of efflux is equal to that a body that falls freely by a vertical distance 'h'. This is the famous Torricelli Law. Observe that the velocity of efflux at a point, like pressure at that point, varies as 'h'.

The time of fall is given by: $(H-h) = \tfrac{1}{2} g t^2$

That is: $t = \sqrt{[2(H-h)/g]}$

Range, R = velocity of efflux X time of flight

$R = \sqrt{[2gh]} \text{ X } \sqrt{[2(H-h)/g]}$

$R = 2 \text{ X } \sqrt{[h(H-h)]}$

For R to be maximum, we set $dR/dh = 0$

$d(\sqrt{h(H-h)})/dh = 0$

That is: $\sqrt{[h]}\,[-1/2 * \sqrt{h}] + \sqrt{[(H-h)/2} * \sqrt{h} = 0$

$(h-H) = -h$ or $h = H/2$

This shows that the hole must be at the midpoint for the range to be a maximum. Then the range is

$R_{max} = H/2$

Similarly, one can show that the water coming out of the 25 cm mark and the 75 cm mark have the same range and is equal to 0.866 H. This is because the product of 'h' and (H-h) is same on account of the symmetry in the position of the holes.

In conclusion, we may say that the flow of water through a hole in an open container follows the equations of motion for a projectile without air resistance. And, that one has to consider both velocity of efflux as well as the distance of the hole from the bottom of the pipe in determining the range covered by water.

The above expressions have been experimentally verified using a 60 cm long, 5cm diameter GI pipe. The holes were 2mm in diameter. The calculated ranges and the experimental values were within 5% of the theoretical values. We used a 1/80 hp submersible pump used for indoor fountains, to maintain a constant water level in the pipe. The experimental set up is extremely useful to carry out investigations in projectile motion. One word of caution must be made here though. Since the calculations are based on Bernoulli principle, it is essential that we deal with 'incompressible', 'non-viscous' fluid flowing without any turbulence.

(Reference: Fundamentals of Physics by Resnick, Halliday and Jearl Walker Physics for Scientists and Engineers by Serway)

Edited & Published by
The Director
JAWAHARLAL NEHRU PLANETARIUM
Sri T. Chowdaiah Road, High Grounds, Bengaluru-560 001
Ph: 080-22379725, 22266084
E-mail: info@taralaya.org   Website: www.taralaya.org