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Contents

News:

The detection of gravitational waves

Gravitational waves are small ripples in space-time that travel across the universe at the speed of light. They were predicted to exist by Albert Einstein in 1916 as based on his General Theory of Relativity. Following this a series of studies by Karl Schwarzschild, Chandra Sekhar, Robert Oppenheimer and Roy Kerr led to the exploration of the properties of black holes. Do they exist, if so, how to observe them?

C. V. Vishveshwara had published three papers during 1968-70 in black hole physics and gravitational radiation and analyzed for the first time the structures of both types of black holes, one static and the other spinning. In the paper published in Nature, he demonstrated that the gravitational wave packets scattered by the black hole emerge in the form of quasi-normal modes as the signature of the black hole. He had identified the characteristic ringing modes of a black hole. Forty-five years after Vishveshwara's work, LIGO recorded the quasi-normal modes emitted by a larger black hole produced by the merger of two smaller ones. This, therefore, is the first ever experiment detecting gravitational waves from a black hole.

Jawaharlal Nehru Planetarium is very proud that as its Founder Director, Vishveshwara initiated production of Sky-Theatre programs for the first time in India; he also introduced non-formal educational programmes for students at all levels from primary school to undergraduates, rendering the Planetarium as a unique institution. Prof B R Iyer, Chair of the IndiGO Consortium, has been contributing to the educational activities for over a decade and is on the Governing Council, BASE.

A press meet organized on February 26 provided opportunity for a good interaction with Profs U R Rao, Chairman, Governing Council, BASE, C V Vishveshwara and B R Iyer.

The Solar Eclipse of March 9, 2016

The beginning of totality as seen from Palangkaraya, Indonesia. (photo B S Shylaja)

The "short" eclipse from Lalbagh, Bengaluru (photo: Pramod Galgali)

Good bye to the "old faithful"!

The Spacemaster projector which served for over 25 years and entertained more than 50 lakh visitors was brought down on March 3rd making way for the new hybrid system. The staff gathered together for a farewell.

The Literature of Science

.....(Continued from previous issue) - *S Lokanathan*

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. ....

For all that, Darwin needed the support of those who could show more aggression in the ensuing controversy. Perhaps the foremost of them was Thomas Huxley whose own ideas on Physical anthropology were stimulated by Darwin's work. Two of Thomas Huxley's grandsons, Sir Julian Huxley and Aldous Huxley became renowned writers in their own fields, Julian as a Biologist who wrote on cultural and biological possibilities of evolution and Aldous as a novelist concerned with the less palatable effects on human relations thanks to advances of Science. In one of Sir Julian's essays [9], he wrote on the interesting contrast in the time scales of 'evolution' in the organic and inorganic worlds: "Evolution in the comprehensive sense is unique, one way, irreversible process in time, generating novelty and variety. During the process, an immense increase in organization has been produced, but only in a few sectors in which conditions have been favourable. In the Universe at large, evolution has remained on the inorganic level; its rate has been exceedingly slow, and the degree of organization it has produced has usually not exceeded the atomic. On our earth, conditions permitted the formation of complex organic molecules capable of self-reproduction. A new mechanism of change became available in the shape of natural selection.....and the biological phase of evolution was thereby initiated. The process of evolutionary transformation was much accelerated ...". It is fascinating, this comparison of change in the inorganic and the organic – recall Nagel's comment on the difference in the language of Physical and Biological Sciences. The problem here, it seems to me, is the notion of 'organization'. Physical Scientists would probably regard the idea of any 'purposive' organization as an anthropocentric view. On the other hand, cosmologists today are not hesitant to speculate on the changes in the Universe following the Big Bang. Indeed the Nobel Laureate Steven Weinberg has written a charming little book on 'The First Three Minutes'.[10] Even on a biological scale that is fast!

Darwin's work preceded any knowledge of the mechanism of heredity, its particulate character. That came in 1866 from a most unlikely source, the publication of an Austrian monk, Gregor Mendel. His experiments on a hybrid of tall and short garden pea plants, carefully crossed, showed that in the second generation three fourths are tall and one fourth short. He reported "..If now the results of the whole of the experiments be brought together, there is found, as between the number of forms with the dominant (i.e, tall) and recessive (short) characters, an average ratio of 3 to 1"[11] . That chromosomes are the distributing mechanisms in heredity was to emerge later; indeed the importance of Mendel's work was recognized several years after its publication.

I had talked of the liberation of Science from religion. But the new developments in Biology renewed conflicts with ideology. The particular point at issue was the basis of heredity – whether it could be permanently conditioned by Social factors. In the late 1940's, Soviet Genetics came under the authority of T.D.Lysenko who asserted (resurrecting Michurin's work) that acquired characters are inherited in each generation through (incremental) modifications. Subsequently Lysenko's power, in political circles, was to affect the growth of Soviet agriculture. A remarkable book (Soviet Genetics) by Julian Huxley [9] goes into the history and the technical aspects of this controversy.

Some 15 years after the 'Origin' Darwin wrote 'The Descent of Man' perhaps as a now defiant gesture to the fundamentalists. Clearly, Darwin's use of the word 'Descent' was in consonance with Evolution. It is amusing that works now appear talking of the 'Ascent' to mean nearly the same thing! In 1972, Dr. J. Bronowski's 'Ascent of Man' [12] was published following a brilliantly produced B.B.C Television series. This book covers the History of Man and his Science, from his crude tools to his modern sophisticated theories and technologies. For all its brilliance of exposition, this book provoked an eminent philosopher friend of mine to remark "It should have been called the Ascent of Western Man". Indeed the work hardly mentions other cultures but the omission, one senses, is not wanton. The problem is that despite the claim of this or other histories, the growth of Science is hardly on the usual historic scale of time. (Galileo is almost a modern man). And this growth has coincided with the ascendancy of the West. On the other hand, interesting science-aided human histories are resurgent (there are, in some Universities, courses in Archaeometry) and one hopes that these will not exhibit the ethnocentricity complained of.

I had said that naive reductionism, such as the attempt to explain electromagnetism by mechanical theories, failed.

But great recent advances in Life Sciences, especially in Genetics, have come from discoveries of structure and processes from a molecular basis which owe their origin to Physics and Chemistry. The Physicist, Erwin Schrodinger, one of the founders of Quantum Mechanics, delivered a series of lectures at the Dublin Institute of Advanced Studies and these were published in 1945 under the title: 'What Is Life'(13) . The particular point that seems to have triggered Schrodinger's curiosity is the amazing 'hardness' of a gene, i.e, its capacity to go through generations without change except when a discontinuous mutation occurs. For Schrodinger, this suggested that the dictates of Quantum (rather than Classical) Mechanics play a pivotal role in cell processes. Many feel that this remarkable work is one that encouraged a spurt of activity in the field of Molecular Biology. In fact one of the great discoveries in Life Sciences, the double helix structure of DNA, acknowledged by Nobel awards in 'Physiology and Medicine', was by Crick and Watson whose early training was as Physicists. Perhaps Nobel's failure to institute an award for biological sciences was because of his confidence in the future trend towards unification of the Sciences!

One of the finest popularizers of Science was the brilliant biologist, J.B.S.Haldane, who spent his last years in India because he wanted to find a haven for his humanism. In one of his books, a fine collection (14) titled 'On Being the Right Size and Other Essays' he discusses a variety of themes, ranging from the relation of the size of animals and its living conditions to an essay 'The Biology of Inequality' in which he effectively dismisses the use of Darwinian selection as an excuse for domination by the elite.

In the early 1960's, one of India's brilliant mathematicians, D.D.Kosambi published 'The Culture and Civilisation of Ancient India' (15) . In his preface Kosambi called himself a 'free agent' (i.e, not a regular professional Historian). For all that the work is a product of an original field study culminating in his interpretation of coins and microliths. His style is short and pithy. Our Indian chauvinists were given short shrift on thoughts of any 'Golden Age' in the past. "Human bones dug up after several tens of thousands of years show that it was a spectacular achievement for any Stone Age man to reach as much as forty years of age; far from being healthier, he suffered even more than we do from parasites and crippling illness that shortened his life. The golden age, if any, lies in the future, not in the past". But then one must emphasize that Kosambi's was not the usual chronicle of kings and empires. Taking his cue from Karl Marx he defines his goal: "History is the presentation in chronological order of successive changes in the means and relations of production". His success prompts me to include this in my collection of 'Scientific Literature'. After all his tools and the objectivity of interpretation that he strove for are indistinguishable from the methods of Science.

If Darwin was the great philosopher-Scientist of the nineteenth century, Albert Einstein would be nearly everyone's choice for that mantle in the twentieth. Einstein himself was a superb exponent of not merely his own contributions, Relativity in particular, but of the whole of physics. Moreover, his work inspired some of the finest writings on Science. Among Einstein's many contributions, I shall select a sample from his book "The World As I See It"(16). His introductory remarks on the problem of Space are illuminating: "There are two ways of regarding concepts, both of which are necessary to understanding. The first is that of logical analysis ......It is the security by which we are so much impressed in mathematics. But this security is purchased at the price of emptiness of content. Concepts can only acquire content when they are connected, however indirectly, with sensible experience". Einstein here explains with clarity the distinction between 'Physical' space and the abstract 'Mathematical' space. His succinct comment 'As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain they do not refer to reality' is the remark of a person with profound understanding of the role of pure thought as well as empiricism.

A superb account of the revolutionary ideas of Relativity is in "The Evolution of Scientific Thought from Newton to Einstein" by A.d'Abro (17) . This popular exposition describes difficult concepts: "Mathematical space is amorphous; it possesses no intrinsic metrics and our choice of standards is largely arbitrary". The book ends with a long chapter each on the 'Methodology of Science' and on the 'General Significance of Relativity'.

One should not be surprised that I choose the writings of Richard Feynman among my most memorable reading. It is not just that as a Physics teacher, I look up to one of the greatest Physicists of our times. He brought to both pedagogy and to popular writing a style that was original, witty and totally devoid of pomp. In his preface, he chose this quotation from Gibbons to moderate any feeling of euphoria on the success of his 'Lectures on Physics': "The power of instruction is seldom of much efficacy except in those happy dispositions where it is almost superfluous". His disarming simplicity disguised his profound understanding of the growth of Science. In his Nobel lecture, he summed up the current status of the theory (i.e, Quantum Electrodynamics): "So what happens to the old theory that I fell in love with as a youth? Well I would say it's become an old lady, that has very little attractive left in her and the young today will not have their hearts pound when they look at her any more. But, we can say the best we can for any old woman, that she has been a very good mother and she has given birth to some very good children"[18] .

There are a number of very readable biographies. Again my selection is a limited personal choice. Abraham Pais's 'Subtle is the Lord' is one of the best on Einstein's Scientific Life, enriched by the author's long association with Einstein in the Institute of Advanced Study in Princeton [19] . Feynman's autobiographical sketches in two slim books [20] are a delightful read.

Students may have reservations about the value of such extra- curricular reading. Textual knowledge makes little demand on the history of ideas. After all the 'names' in a text book are not very important. For example, there is some controversy about the priority of the so called 'Snell's Laws' in geometrical optics. There is reason to believe that he was anticipated by Arabs by a few hundred years. For a literature student the question of originality is of more serious concern. Still, the idea of 'pure knowledge' devoid of its historic or social context is illusory even in Science. That most fruitful hypothesis, that all matter is made of discrete things called atoms, has a very long history. But its contextual development shows how the very meaning of 'atoms' has changed and a historic view deepens one's understanding.

Our interest in Science Literature may be read for profit and that is laudable; or we may read for pure pleasure and that, if not entirely innocent, need not cause harm. I am reminded of the response of the brilliant English essayist, Priestley who responded to the very stern critic of English Literature, F.R.Leavis, for whom it did not seem that there was much great literature beyond some half a dozen of his choice. Priestley said that if some parent of a potential student of literature came to him and said that his daughter had to finish her education in short order and 'what should she read', he would reply "certainly not Priestley!". But choices are not like that. And even if they are it is difficult for others to make them for you. So let your instinct serve you – after you try a few.

References:

9. Julian Huxley, born in 1887, was an eminent British Biologist and a fine writer. He served as the Director-General of UNESCO for some time. The essay cited appears in a collection published in a book: 'Knowledge, Morality & Destiny', Mentor Books, N.Y (1957). One of his earlier books, 'Soviet Genetics and World Science', published by Chatto and Windus in 1949, was a powerful criticism of the state of Biology in Soviet Union thanks to the ideological demagoguery of T.D.Lysenko.

10. Steven Weinberg, Nobel Laureate (Physics), wrote a popular exposition of the current knowledge formation of the early Universe, a blow by blow account of the first few minutes of the Big Bang: "The First Three Minutes" Basic Books, N.Y (1977).

11. In a sense Mendel's discovery 'saved' Darwin's theory. Original versions of heredity were based on the assumption that the biological characteristics transmitted were a blend of those of the parents. This would imply that any new characteristic (acquired by natural selection) would be diluted rapidly.

    Mendel's work showed that (certain) characeristics were retained without any dilution or blending as if they were passed on by a 'particle'. It is this 'hardness' (i.e, resistance to any small change that stimulated Schrodinger's 'What is Life'. Huxley's book on Soviet Genetics (ref. 9 above) discusses this. For the ref. to Schrodinger's work, see (13) below.

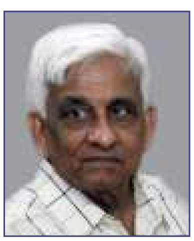
12. J. Bronowski, was born in Poland in 1908 and settled in Britain. A fine Biologist, he was known for his popular Science presentations on B.B.C. This famous series was in thirteen parts and was published by B.B.C in book form: "The Ascent of Man" (1973).

13. Erwin Schrodinger's 'What Is Life' was published by Macmillan Co in 1945; extracts from this are included in Volume II of the 'The World of Physics' (See ref #2 above). Crick's Nobel lecture is also included in this volume.

14. J.B.S.Haldane was a brilliant geneticist and wrote extensively on evolution. He was a communist but not a doctrinaire one. His criticism of cold war politics made him unwelcome in his home country, England, and he settled down in India in his late years and died there in 1964. His 'On Being the Right Size and other essays' was published in a paperback edition by Oxford University Press (Delhi) in 1992.

15. D.D.Kosambi was a brilliant professional mathematician and only in his late years turned to a systematic study of Ancient Indian History. An extraordinarily versatile scholar, his field studies and his work on numismatics and microliths made him famous as a Historian even though he modestly thought of himself as an amateur. 'The Culture & Civilisation of Ancient India' was published by Vikas Publishing House, New Delhi in 1970.

16. Albert Einstein's reputation as a physicist is perhaps rivalled only by Isaac Newton. He wrote with great clarity, be it a technical paper or a popular exposition. 'The World As I See It' is from a collection 'Man and the Universe: The Philosophers of Science', Random House, N.Y (1947). The quote about the relation between mathematical laws and reality is from a work republished by Dover, N.Y in 1983: 'Sidelights on Relativity'.
17. d'Abro's excellent book was published as a Dover (N.Y) edition in 1950;
18. The Feynman Lectures on Physics have set a new standard on the teaching of Science to young students. It was first published by Addison-Wesley in 1965. Feynman's Nobel Lectures is reprinted in 'The World of Physics' Volume II, edited by Jefferson Hane Weaver, published by Simon & Schuster, N.Y (1987).
19. A.Pais was for a number of years, a colleague of Einstein at the Institute of Advanced Study at Princeton, N.J. He has also published other biographies, notably on Niels Bohr. This one on Einstein is on Oxford paperbacks, Oxford University Press, Oxford (1982).
20. The two books 'Surely You're Joking, Mr. Feynman' and 'What do You care What Other People Think' are called 'adventures' of the author in the blurb and they are that – rather than a conventional autobiography. But they offer an insight to a life of scientific integrity. The second book has a long closing section on Feynman's experience as a member of a committee investigating the disaster of the space shuttle 'challenger' (in which seven astronauts perished) which is a testament to what he stood for. The two books are the publication of W.W. Norton & Co, New York.



A look at the Wonderful World of Light- II

QUANTUM OPTICS

-G.S. Ranganath

In the first part of this article, we presented a few interesting research topics in ray and wave optics. We consider here phenomena that can be understood as a consequence of the quantum nature of light. Towards the end of the article we dwell upon the quantum description of some well known features of a light wave.

LUMINISCENCE

We know very well that Albert Einstein proposed the quantum nature of light to account for the phenomena of luminescence, photoelectric effect and photo-ionization. In this model light behaves as a stream of particles called photons. Each photon is of energy $h\nu$, where h is the Planck's constant and ν the frequency of the light wave. In view of the Special Theory of Relativity, a photon will have a mass m equal to $h\nu/c^2$ and a momentum of $h\nu/c$.

We consider here the phenomenon of Luminescence as it is the simplest of the three effects that can be understood in the quantum picture of light. In 1852 Irish physicist G. G. Stokes discovered that, a monochromatic light beam falling on a luminescent material is re-emitted by the medium but always with a lesser frequency. For example, blue light falling on the dye Rhodamine 6G, leads to luminescence in the red part of the spectrum as depicted in Fig.1a.

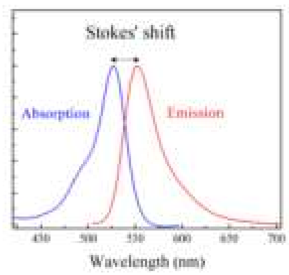


Fig.1a. Absorption and emission spectra of Rhodamine 6G (Stokes Shift-Wikipedia)

The wave theory of light could not explain this effect at all. Einstein explained this phenomenon beautifully on the photon picture of light. The incident photon loses energy to the medium and emerges with a lesser energy or frequency. His theory is diagrammatically illustrated in Fig.1b.

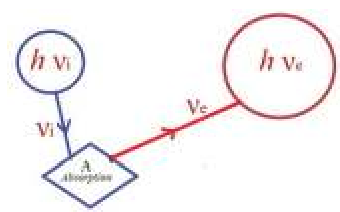


Fig.1b.Phenomenon of Luminescence: ν_i is the incident frequency and $\nu_e < \nu_i$ is the emitted frequency.

Fluorescence is a closely related process. Illuminating a fluorescent material with the ultraviolet light leads to emission in the visible part of the spectrum. This phenomenon has been used to see objects and materials that are invisible in the visible part of the spectrum. By a clever manipulation of laser optics and fluorescence, the German physicist Stefan Hell successfully overcame the diffraction limit of resolution. He developed in 2000 a Fluorescence Microscope that could reveal structural details at any desired sub-wavelength scale.

LIGHT SCATTERING

We can understand luminescence as arising from absorption of a part of the energy of the incident photon.

But this is not the only process occurring in a medium. While studying luminescence, C.V. Raman made a great discovery in 1928. He noticed that the molecules of the liquids scatter incident light in different directions with different intensities. Further he discovered that in any given direction most of the scattered photons have the same energy (frequency) as that of the incident photon. This is the familiar Rayleigh scattering that is responsible for the blue colour of the sky. A small fraction of the incident photons will either lose energy to the molecules that are in the lower energy state or gain energy from the molecules that are already in the excited or higher energy state. This is the famous Raman Effect. Thus in Raman Effect the photons that emerge from the medium are of three types:

(1) Photons of the same energy (Rayleigh) as that of incident photons.

(2) Photons of a higher energy (anti-Stokes) than that of the incident photons

(3) Photons of a lower energy (Stokes) than that the incident photons.

Since at any temperature there will be fewer molecules in the excited state compared to the number of molecules in the ground state, there will be fewer higher energy photons than lower energy photons. Incidentally, this process is called *Spontaneous Raman Scattering*. The essentials of the Raman Effect are shown in Fig.2. It must be remarked that the Raman Effect can take place for any frequency of incident light whereas luminescence takes place around a specific frequency. The frequency of the Raman scattered light has a constant separation from the frequency of incident light.

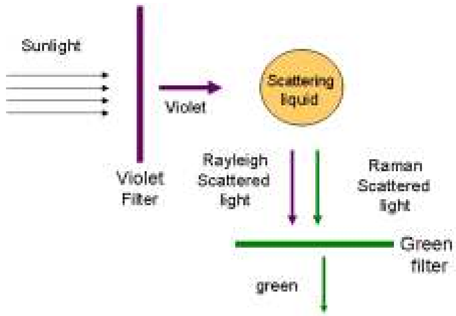


Fig.2. Raman Effect (Raman_effect.pngWikipedia)

With the advent of lasers a new effect has been discovered called the *Stimulated Raman Scattering.* This takes place when some Stokes photons that have already been generated in the medium interact via optical nonlinearly with the original laser light or pump light. In effect this *amplifies* the Stokes light in the presence of the pump light. This is the mechanism behind the *Raman Laser Action*.

Raman Effect helps scientists to work out the structure of molecules. In 1998 the American Chemical Society declared the Raman Effect a *National Historic Chemical Landmark* in view of its use as a powerful tool for analyzing the composition of solids, liquids, and gases.

PHOTONS IN A GRAVITATIONAL FIELD

If a light beam is travelling vertically up, the photon will have to work against gravity and loses energy equal to *mgh* after reaching a height *h*. Thus its frequency will decrease or, in other words, it will get red-shifted. If the light beam were to be travelling vertically down we expect the exact opposite effect to occur. The photon will gain energy equal to *mgh* after falling through a height *h*. In this case its frequency will increase or, it will get blue-shifted. In 1960 R.V. Pound and G.A Rebka experimentally verified this effect at the Jefferson laboratory Harvard University, USA. They allowed gamma ray photons from the radioactive ^{57}Fe source to travel up or down between the basement and the roof that was at a height of 22.5 meters. The frequency change was expected to be from 10 to 50 hertz i.e. a few parts in 10^{15}. They verified that the observed effect agreed with theory to within 10%.

PHOTONS AND THE WAVE DESCPRIPTION

Doppler Effect

The familiar Doppler Effect in sound or light refers to the increase or decreases in the frequency of the wave as the source approaches or recedes from an observer. In a simple language the frequency shift occurs because as successive waves are emitted from the moving source the waves get compressed or stretched as the source moves towards or away from the observer. This process is schematically shown in the Fig. 3a.

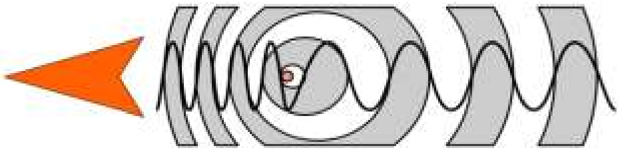


Fig.3a. Doppler Effect-Change of wavelength caused by motion of the source. (Wikipedia)

The Special Theory of Relativity dictates that even for light travelling in a direction perpendicular to direction of motion of the source there is a change in the frequency. This effect is known as the Transverse Doppler Effect. At the point of closest approach between the observer and the source, the light emitted will be red-shifted. And the light received will be blue-shifted. Transverse Doppler Effect is a consequence of the time dilatation predicted by the Special Theory of Relativity.

What is not generally appreciated is that the Optical Doppler Effect can also be explained on the photon picture of light as was shown by the eminent physicist Erwin Schrodinger in 1922. An excited atom travelling at a certain velocity emits a photon in a certain direction and afterwards travels in a different direction with a different velocity as shown in Fig.3b.

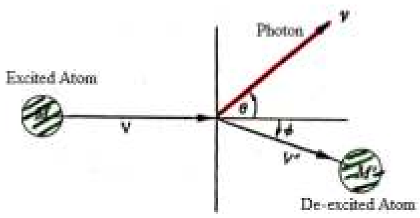


Fig.3b. Quantum theory of Doppler Effect

By balancing the energy and momentum involved in the process and assuming the mass of the atom to be very much more than the mass of the photon, one gets the Doppler frequency shift. This analysis naturally leads to both the longitudinal and transverse Doppler Effects. The results are in complete agreement with what is derived from wave optics.

Propagation of light

If light behaved like particles, it is relevant to ask as to what the particle size might be. Austrian physicist Victor F. Weisskopf argued that a photon behaves as a particle of size of the order of wavelength of light. This picture of a photon has some important implications.

If photons had a finite size comparable to the wavelength of light, then it should not be possible for photons to go through apertures that are narrower than the wavelength of light. This is what even the wave optics predicts and it has even been established experimentally. In fact, it emerges out as an evanescent wave.

It is also obvious that photons should go straight like bullets through apertures that are far wider than the wavelength of light. This result is consistent with the prediction of wave optics according to which light travels as rays for wavelengths much smaller than the aperture size. Further, in this limit, we can say that the photon obeys, like the light ray, the Fermat's principle of least time. This means photon travels along a path of least time after exploring the neighbouring paths. At a boundary, of the many incident photons a few get reflected and the rest enter the medium. Momentum conservation leads to the laws of reflection and refraction.

What happens at intermediate sizes of apertures? The American physicist Richard P. Feynman argued that the photon, while trying to find out the paths of least time, will err since the screen will prevent a complete exploration of the all neighbouring paths. Understandably, this error will be different for different photons. Thus different photons will emerge out of the aperture in different directions. This is the essence of the phenomenon of diffraction. This too is in conformity with experiments and wave description of light. Optical diffraction is seen whenever the aperture size is comparable to the wavelength of light.

Conclusion

The salient aspects of Light can be understood by postulating that light behaves as a stream of particles each of energy $h\nu$, momentum $h\nu/c$ and size comparable to the wavelength of light.

REAPers Speak:

M-dwarfs as extra-solar planet hosts

-Lalitha Sairam

The discovery of the first exoplanet 51 Peg b in 1995 marked the dawn of the new field called the exoplanetary science. Over 1500 exo-planets have been discovered, so far. The majority of the planets detected are Jupiter mass planets, however, the frontier is inevitably moving towards Earth-mass regime. In fact, a handful of super-Earths, i.e., planets with a mass between 1-10 Earth masses have been discovered. However, an ultimate goal is to search for an Earth-like planet.

One of the biggest questions that has puzzled us is if there is life on other worlds somewhere out in the Universe? As it turns out, advancement in the field of astronomy and astrophysics, as well as the technology, can finally begin to answer this question. One can, at least, attempt to detect building blocks of life if the planet is in its habitable zone which is the region around the star where liquid water may be present on the surface.

The first step is to find another planet like our own Earth. A planet can be determined by the transit method which involves looking at the stellar light for a long time and hoping to see a dip in the stellar light when a planet crosses in front of its host star. This is one of the most fruitful methods for determining an exoplanet. So far several surveys of exoplanets around stars have been carried out using transit method. In 2009, NASA launched a space telescope called *Kepler* to search for transiting Earth-sized planets. This mission was a resounding success, finding thousands of planetary candidates in only a few years of observations.

One of the most surprising results from *Kepler* Mission was that most terrestrial planets found were primarily orbiting small stars known as M-dwarfs, which are fainter, lighter and smaller stars than our very own host, the Sun. They make up nearly 75% of the stellar population in our galaxy, making them the most common potential exoplanetary hosts. M dwarfs are in the focus and planned surveys for habitable planet. *Kepler* Mission has succeeded in finding a planet that has a radius very close to that of the Earth in the habitable zone of a M-dwarf star.

However, one key question remains: If the characteristics of M-dwarf planet in its habitable zone provide a suitable environment for life ?

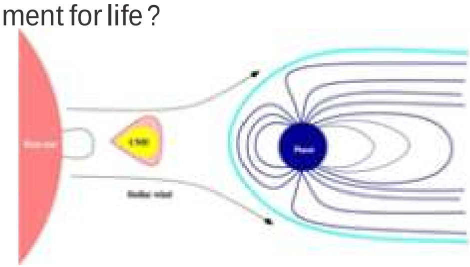


Figure 1: Schematic representation of the influence of M-dwarf star activity on the atmosphere of an Earth-like planet

The intrinsically low luminosities of M-dwarfs shrink the habitable zone around them. Therefore the planets are extremely vulnerable to the stellar radiation and activity, arising out of dynamically evolving magnetic fields produced in the stellar interior. These magnetic fields are responsible, e.g., for the presence of starspots, chromospheric heating, and stellar flares. Stellar activity can produce enormous amount of radiation in wavelengths like X-Ray and EUV which can be absorbed by the planetary atmosphere. Due to extra energy deposition, the exospheres of the planet orbiting close to the star may be heated to chromospheric temperatures resulting in a mass-loss of the atmosphere of the orbiting planet. Hence, the mass-loss rate directly depends on the incident X-ray and UV flux on the planet. Further, stellar activity is also of concern for continuity of habitability since M-dwarfs are well known as active stars showing several flares per hour. Stellar flares can lead to coronal mass ejection and stellar winds which can compress the magnetosphere of Earth-like planets inside the close-in habitable zone, as well as affect the atmosphere and make it unstable. In Figure 1, we schematically represent an Earth-like planet's magnetosphere influenced by the activity on its M-dwarf host star.

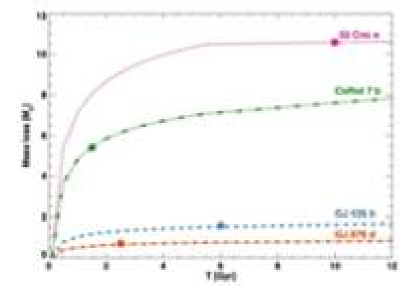


Figure 2: Evolution of mass-loss for super-Earths as a function of its age. The circles represent the current age of these systems.

Since X-ray and EUV are main drivers of planetary evaporation we are currently measuring the X-ray and UV luminosities of several Earth-like planets around M-dwarf. In Figure 2, I show the mass-loss history of some of the well-studied super-Earths. The circles in this figure indicate the current age of the system. For planets CoRot-7b and 55 Cnc e, the X-ray and UV flux from the star seem to have evaporated substantial part of the mass. We estimate that these planets have already lost around 1-10 Earth mass of its atmosphere. We are currently modelling the possible effects of stellar activity like flares on the mass-loss rate of the atmosphere of the planet.

Lalitha Sairam, (REAPer during 2006-9), recollects the foundation laid by REAP with gratitude. She is with the Indian Institute of Astrophysics, after her PhD from University of Hamburg. She is interested in understanding how a star can decide the fate of an orbiting planet around it, which involves the study of frequent and powerful stellar flares. Most of her work is based on multi-wavelengths monitoring campaigns using both space-based telescopes (Chandra, XMM-Newton, Swift, Suzaku, Astrosat) and ground-based telescopes (HCT, VBT and VLT).

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