Albert Einstein: His Miracle Year (1905)

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*** Survival of London from Great fire;**

Victory of English Fleet over Dutch

1666 : Annus Mirabilis of Isaac Newton

In the beginning of the year 1665 I found the Method of approximating series and the Rule for reducing any dignity [power] of any Binomial into such a series [i.e., the binomial theorem]. The same year in May I found the method of Tangents …, and in November had the direct method of fluxions [i.e. the differential calculus] and the next year in January had the Theory of colours and in May following I had entrance into [th]e inverse method of fluxions [i.e., the integral calculus]. And the same year I began to think of gravity extending to [th]e orb of the Moon and (having found out how to estimate the force with w[hi]ch [a] globe revolving within a sphere presses the surface of a sphere [i.e. the centrifugal force]): from Kepler's rule of the periodical times of the Planets being in sesquialterate proportion of their distances from the centers of their Orbs [i.e., Kepler's third law], I deduced that the forces w[hi]ch keep the Planets in their Orbs must [be] reciprocally as the squares of their distances from the centers about w[hi]ch they revolve: and thereby compared the force requisite to keep the Moon in her Orb with the force of gravity at the surface of the earth, and found them answer pretty nearly. All this was in the two plague years of 1665 and 1666. For in those days I was in the prime of my age for invention and minded Mathematicks and Philosophy more then [*sic*] at any time since[2].

Albert Einstein (1879-1955)

Born : 14 March 1879

Presented a pocket compass (1884)

July 28, 1900 : Granted Diploma by ETH(Z)

Theoretical Physics - 5/6

Expt. Physics	-	5/6
Astronomy	-	5/6
Theory of functions	-	5.5/6
Diploma paper	-	4.5/6

Dec. 13, 1900 : Sends his first research paper for publication to A.P. (Annalen der Physik)

June 23, 1902 : Starts working at Patent Office, Bern on Probation. SF 3500 p.a.

October 10, 1902 : His father dies

Jan. 6, 1903 : Marries Mileva Maric

May 14, 1904 : Birth of first son Hans Albert

Sept. 16, 1904 Confirmed in his job at Patent Office

(1901-1904) : Publishes 5 papers in A.P.

1905 : Annus Mirabilis of Einstein. Completes five papers, including his Ph.D. dissertion, on Statistical Physics, Relativity and Quantum theory.

1905

March 18 : The paper "On a Heuristic Point of View Concerning the Production and Transformation of Light" recd. by A.P. [A.P. **17**, 132-148 (1905)] Light Quantum paper

April 30 : Completes his Ph.D. dissertation "On a new determination of the Molecular Dimensions". Printed at Bern and submitted to Univ. of Zürich (accepted in July). [also A.P. **19**, 289-306 (1906)] Molecular Size paper

May 11 : The paper "On the Motion of Small Particles suspended in Liquids at Rest Required by the Molecular Kinetic Theory of Heat" recd. by A.P. [A.P. **17**, 549- 560 (1905)] Brownian Motion paper

June 30 : The paper "On the Electrodynamics of Moving Bodies" recd. by A.P. [A.P. **17**, 891- 921 (1905)] Special Theory of Relativity paper

September 27 : The paper "Does the Inertia of a Body Depend on its Energy Content" recd by A.P. [A.P. **18**, 639-641 (1905)] $E = Mc^2$ paper

December 19 : Another paper on Brownian Motion submitted to A.P.

A.E. to his friend Conrad Habicht, 18 or 25 May 1905

I promise you four papers …, the first of which I could send you soon, since I will soon receive the free reprints. The paper deals with radiation and the energetic properties of light and is very revolutionary as you will see …. The second paper is a determination of the true sizes of atoms from the diffusion and viscosity of dilute solutions of neutral substances. The third proves that, on the assumption of the molecular [kinetic] theory of heat, bodies of the order to magnitude of 1/1000 mm, suspended in liquids must already perform an observable random movement that is produced by thermal motion; in fact, physiologists have observed motions of suspended small, inanimate, bodies, which they call "Brownian molecular motion". The fourth paper is only a rough draft at this point, and is an electrodynamics of moving bodies, which employs a modification of the theory of space and time; the purely kinematical part of this paper will surely interest you.[4]

Thesis on Molecular Sizes

[1901: Thesis (first attempt) on topic = Boltzmann's gas Theory and Drude's electron theory of metals? Withdrawn by Feb. 1902.

"The whole comedy has become tiresome for me" (A.E. to Michela Besso, Jan. 1903)]

The thesis has 2 main results

(i) Viscosity of dilute solutions:

η_s = viscosity of the solution (solute + liquid)

η = viscosity of the liquid

$\eta_s = \eta\,(1+2.5\varphi)$

φ = fraction of the volume occupied by solute molecules

$= (4\pi/3)\ a^3 \quad N_A \rho_S\ /\ m_S \Rightarrow N_A a^3$

a = radius of molecules,

ρ_S = mass density of the solute

N_A = Avogadro number

m_S = molecular weight of the solute mole.

(ii) Diffusion Coefficient D at temp T

$D = RT/(6\ \pi\ \eta\ N_A\ a)$ R = gas constant,

$\Rightarrow N_A\,a$ PV = RT

$(N_A\,a^3,\ N_A\,a) \Rightarrow (N_A\,a\ )$

- A.E. chose the topic himself as was acknowledged by Alfred Kleiner, who reviewed the thesis along with H. Burkhardt. A.K. was professor of experimental physics at ETH. ETH was not allowed to grant Ph.D. degree till 1909. H.B. was Professor of Mathematics at Univ. of Zürich. (missed 2.5 too).
- Einstein motivated the thesis by pointing out that this is first determination of <u>a</u> using liquids. Earlier one depend on Kinetic theory of gases.
- A.K.: "the arguments and calculations to be carried out are among the most difficult in hydrodynamics".
- H.B.: "The mode of treatment demonstrates fundamental mastery of relevant math. methods." "adding one sentence" (A.E. to Seelig)
- A.E. (1905): $a = 9.9 \times 10^{-8}$ cm (Hydration)
  $N_A = 2.1 \times 10^{23}$

  A.E. (1906) $N_A = 4.15 \times 10^{23}$ (use of improved data)
- Jan 1911: Hopf finds the missing factor 2.5

  A.E. (1911) $N_A = 6.56 \times 10^{23}$ per mol.
- Initially foreshadowed by other (1905) papers

Eventually has the highest citation in view of its use by others.

BROWNIAN – MOTION

1. From the mid – 19th Century, the atomic hypothesis was rapidly gaining ground among physicists and chemists.
2. "Energeticists": W. Ostwatd, Georg Helm, Evan E. Mach was also hostile to Atomists. They only admitted to heuristic usefulness of Atoms.
3. "In this paper it will be shown that according to <u>molecular-kinetic theory of heat</u>, bodies of a <u>mircroscopically visible size</u> suspended in liquids, must, as a result of thermal molecular motion, perform motions of such magnitude that they can be <u>observed with</u>

a microscope"

"It is possible that the motions to be discussed are identical with so called Brownian molecular motion; however the data available to me on the latter are so impressive that I could not form a judgement".

4. Robert Brown, 1828. random motion of pollen grains in a liquid.

(Drunkard's Walk around a lamp post).

explanation : vital forces, capillarity, convection Currents, evaporation, interaction with light, and elec. Forces etc.

Kinetic Theory (Von Nageli 1879 tried to rule this out)

- A.E. shows that for the suspended microscopic particles the diffusion coefficient D is given by

$$D = RT/(6\pi\eta a N_A)$$

(In thesis, the same expression had occurred for solute molecules. Here it is for suspended particles. For this he first shows that Vant-Haff's law of osmotic pressure is valid for both solute molecules and suspensions using Molecular – Kinetic theory of Heat). Using diffusion equation he shows

$$(\overline{X^2}) = 2\,D\,t.$$

- J. Perrin (1908-…) Beautiful expts on Brownian motion of colloidal particles

⇒ precise value of Avogadro Number

⇒ Triumph of Atomism, even Ostwald was convinced

"The atomic theory has triumphed. Until recently still numerous, its adversaries, at last overcome, now renounce one after another their misgivings, which were for so long, both legitimate and undeniably useful". (J. Perrin, *Les Atomes*, 1913) Nobel Prize to Perrin in 1926.

- Fluctuation Phenomenon, Stochastic Processes, …

SPECIAL THEORY OF RELATIVITY

Background :

- Newton's dynamical laws, *Principia* (1687).

  - point particles and forces
  - gravitational force
  - light
  - **absolute space and time**,

- Young, Fresnel, Fraunhofer, …

  - interference, diffraction ⇒ Waves
  - medium : luminiferous aether

- Faraday - Field concept

Maxwell - Electromagnetic Field

Electromagnetic waves of a constant velocity. Maxwell identifies light with E-M wave

- Two clouds on the Horizon

Problem of velocity of earth through aether

Newton's laws are same in all inertial systems *i.e.* all those systems which are moving in a straight line with constant velocity with respect to each other.

Rules for comparing : Galilean transformations

Maxwell's E.M. Theory in not the same in all systems connected by Galilean transformation. It should therefore be possible to determine earth-aether relative velocity. Experiments always give a null result.

Einstein's resolution

1. Banish aether
2. A thorough revision of the concept of space and time

Simultaneity :

He found that the two considerations

(1) All physical laws have the same form in all inertial frames

(2) The velocity of light is same in all initial frames, which look **irreconcilable**, can indeed reconciled if space and time notions are brought into line with his `analysis of simultaneity.

- Galilean transformation $\Rightarrow$ Lorentz transformation
- Newton dynamics has to be modified so that is invariant under Lorentz transformation
- Length – Contraction (Fitzgerald – Lorentz); time – dilation (Einstein), mass variation with velocity, …
- War bond rally in Kansas in 1944. \$6.5m.
- Minkowsk i: (1908) Hereafter space and time by themselves are bound to fade away and only a union of the two will reserve an independent unity.

Translated from *Annalen der Physik* 18 (1905) *page 641*

Neglecting magnitudes of the fourth and higher order, we can get

$$K_0 - K_1 = (L/V^2)\, v^2/2$$

From this equation one immediately concludes :

If a body emits the energy L in the form of radiation, its mass decreases by L/V^2. Here it is obviously inessential that the energy taken from the body turns into radiant energy. So we are led to the more general conclusion.

The mass of a body is measure of its energy content. If the energy changes by L, the mass changes in the same sense by $L/(9.10^{20})$ if the energy is measured in ergs and the mass in grams.

It is not excluded that it will prove possible to test this theory using bodies whose energy content is variable to a high degree (e.g. radium salts).

If the theory agrees with the facts, then radiation carries inertia between emitting and absorbing bodies.

A.E. to his friend Conrad Habicht, 30 June -22 Sept. 1905

One more consequence of the paper on electrodynamics has also occurred to me. The principle of relativity, in conjunction with Maxwell's equations, requires that mass be a direct measure of the energy contained in a body; light carries mass with it. A noticeable decrease of mass should occur in the case of radium. The argument is amusing and seductive; but for all I know, the Lord might be laughing over it and leading me around by the nose.[5]

1907 : Discovers Principle of Equivalence

1912-13 : Metric tensor description of gravitation

1915 : Nov.25 Completes his formulation of General Theory of Relativity (G.R.)

Flat space-time (Euclidean)

↓

(Riemannian) Curved space-time gravitation » curvature of space – time

1917 : First paper on Cosmology

1919 : May 29 Eddington total solar eclipse expedition confirms G.R. Becomes a world-wide icon.

1922- .. : Unified field theory

QUANTUM REVOLUTION

- Origins in the Problem of Black Body Radiation
- Kirchhoff : 1869 a universal function of λ and T
- Max Planck succeed: Kirchoff (1889)
- Planck's Oscillators: (18.5.1899)
- Rayleigh – Jean's Law (June 1900, 1905)
- If Planck had known Equipartition theorem of energy ½kT
- Rayleigh -Jeans good for λ large. Wien's Law (1894) good for λ small
- Planck's law 19 Oct. 1900
- Planck gives a formal derivation on 14 Dec. 1900 to German Physical Society
- $E = nh\nu$
- "This was a purely formal assumption and I really did not give it much thought except that no matter what the cost, I must bring out a positive result".
- A.E.'s Light Quantum paper (Nobel Prize for 1921, announced Nov. 1922)
- Motivation : Asymmetrical treatment of matter and radiation in classical physics (i.e. particles vs fields)

Discrete vs Continuum

"The wave theory, operating with continuous spatial functions, has proved to be correct in representing purely optical phenomena and will probably not be replaced another theory. One must, however, keep in mind that the optical observations are concerned with temporal mean values and not with instantaneous values, and it is possible, in spite of the complete experiment verification of the theory of reflection, refraction, diffraction, dispersion and so on that the theory of light which operates with continuous spatial function may lead to contradictions with observations if we apply it to the phenomena of the generation and transformation of light"

- Black body radiation, photoluminescence, photo electric effect.
- Light quantum hypothesis "in the propagation of a light ray emitted from a point source, the energy is not distributed continuously over ever increasing volumes of space, but consists of a finite number of energy quanta localized at points of space that move without dividing, and can be absorbed or generated as complete units".
- Black-Body radiation: Equipartition theorem of Energy

$$\Rightarrow u(\nu, T)d\nu = \frac{8\pi\nu^2 d\nu}{c^3} kT$$

(i) first correct derivation of the so called Rayleigh– Jeans law

(ii) $\int_o^\infty d\nu \;\; u(\nu, T) = \infty$

(iii) classical physics fails except for λ large

- Wien's law $u(\nu,\text{T}) = a\ \nu^3 \exp(-h\nu/\text{T})$

$\Rightarrow$ $S-S_o = (E/h\nu) \ln(\nu/\nu_0)$

Combining with

$S = k \ln W$

Prob. $W(\nu_0 \rightarrow \nu) = (\nu/\nu_0)^n$, $n = (E/h\nu)$

For an ideal gas of n particles also

Prob. $W(\nu_0 \rightarrow \nu) = (\nu/\nu_0)^n$

"Monochromatic radiation … behaves in thermodynamical theoretical relationship as though it consisted of distinct independent energy quantum of magnitude $h\nu$"

Applications

(i) Stokes law: $h\nu_1 > h\nu_2$

Ionization of Gases by UV light :

Photoelectric Effect :

1887 : H. Hertz
UV light incident on metals can cause sparks

1899 : J.J. Thomson

The sparks are due to the emission of electrons : e/m

1902 : P. Lenard

- "Not the slightest dependence on the light intensity" (variation by a factor of 1000)
- Photoelectron energy ↑ incident frequency (qualitative)

1905 : A. Einstein

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

"The second coming of h" (A.P.)

1915-16 R.A. Millikan

"Einstein's photoelectric equation … appears in every case to predict exactly the observed results … yet the semi-corpuscular theory by which Einstein arrived at his equation seems at present wholly untenable"

"the bold, not to say reckless, hypothesis of the e.m. light corpuscle"

PHOTON

1905 : light quantum $E = h\nu$

1917 : momentum = $h\nu/c$ (A.E.)

1923 : Compton - Kinematics of an electron – "photon" collision [1926: G.N. Lewis introduced the term "PHOTON"]

1924 : S.N. Bose's derivation of Planck's Law using only the particle picture and application of Bose statistics (sometimes called Bose-Einstein Statistics) to matter.

PHYSICS DEPARTMENT
Dacca University
Dated the 4th June, 1924

Respected Sir,

I have ventured to send you the accompanying article for your perusal and opinion. I am anxious to know what you think of it. You will see that (I have tried to deduce the coefficient $8pn^2/c^3$ in Pianchi Law independent of the classical electro dynamics) only assuming that the ultimate elementary regions in the Phase space has the content h^3. I do not know sufficient German to translate the paper. If you think the paper worth publication, I shall be grateful if you arrange for its publication in Zeitschrift für Physik. Though a complete stranger to you, I do not feel any hesitation in making such a request. Because we are all your pupils though profiting only by your teachings through your writings. I do not know whether you still remember that somebody from Calcutta asked your permission to translate your papers on Relativity in English. You acceded to the requests. The book has since been published. I was the one who translated your paper on Generalised Relativity.

Yours faithfully,
S.N. Bose

2. VII,

Lieber Herr Kollege:

Ich habe ihre Arbeit über-
-Setzt und der Zeitschrift für
Physik zum Druck übergeben.
Sie bedentet einen wichtigen
Fortschritt und hat mir
Schr gut gefallen. Ihre
Einwände gegen meine Arbeit
finde ich zwar nicht richtig.
Denn das Wiensche Ver –
Schiebungsgesetz setzt die
undulations theorie nicht Voraus
und das Bohr-che Korrespondenz
prinzip ist uberhaust nicht
Verwendel Joch dies that
Nichts. Lie haben ala erster
den Faklor quantentheoretisch abgeleitet wenn auch wegen
des Polarisations, Jaklors 12
Nicht ganz streng. Es ist
ein schöner Fortschritt

Met Freundlichen Gruss
Ihr A.Einstein
Sd)

Sitz Berlin Pess Akad. Wiss Berlin p. 261 (1924)

Quantentheorie des einatomigen idealen Gases

Von A. EINSTEIN

Eine von willkürlichen Ansatzen freie Qunatentheorie des einatomigen idealen Gases existiert his heute noch nicht. Diese Lücke soll im folgenden susgefüllt warden auf Grund einer neuen, von Hra.D.Bose erdachten Betrachtungeweise, auf welche dieser Autor eine höchst beachtenswerte Albeitung der PLANCKschen Strahlungsformed gegründet hat[1].

Dez im folgenden imAnschuâ an BOSE einzuschlagende Weg laât sich so charakterisieren. Der Phasenraum cines Elementargebildes (hier eines einstoungen Moleküls) in bezug auf ein gegebenes (driedimensionales) Volumen wird in “Zellen” von der Ausdehnung[A] eingeteilt, Sind viele Elementargebilde vorhauden, so ist derren fur die Thermodynamik in Betracht kommende (mikroskopische) Verteilung durch die Art und Weise charakterisicrt, wie die Elementargebilde über diese Zellen verteilt sind, Die “Wahrscheinlichkeit” eines markroskopisch definierten Zustandes (im PLANCKschen Sinne) ist gleich der Anzahl der verschicdenen mikroskopischen Zustande, durch welche der makroskopische “Zustand realisiert gedacht warden kann. Die Entropic des makroskopischen Zustandes und damit das staistiche und thermodynamische Verhalten des Systems wird dann durch den BOLTZNANNSCHEN Satz bestimmt.

§1. Die Zellen.

Das Phasenvolum, welches-zu einem gewissen Bereich der Koordinaten. *x,y,z* und rugehörigen Moments P_1, P_2, P_3 eines einatomigen Moleküls gehört, wird durch das Integral.

$$\Phi = ò\ dx\ dy\ dz\ dp_x\, dp_y\ dp_z \qquad (1)$$

susgedruckt. Ist V das dem Molekul zur Verfügung stehende Volumen, so ist das Phasen volumen aller Zustände, deren Energie $E = 1/2m\ (p_x^2 + p_y^2 + p_z^2)$ kleiner ist als ein bestimmter Wert E, gegeben durch

$$F = V\ \ 4\pi/3\ (2mE)^{3/2} \qquad (Ia)$$

'Erscheint nachstens in der 'Zeitschr für Physik'

1907 : Quantum theory of specific heat of solids

1909 : Wave-Particle duality

1917 : A and B coefficients of Einstein, Discovers Stimulated emission of light (lasers)

1924 : Bose – Einstein condensation (2001 Nobel Prize to Cornell, Ketterle, Wiemann)

1925-26 : Discovery of Quantum Mechanics Schrodinger Wave Mechanics (A.E. as god father); Heisenberg Matrix Mechanics (A.E.'s inspire)

> 1926 : Foundations of Quantum Mechanics

Oct 1927 : Solvay Conference - Discussion with Bohr

1935 : Einstein – Podolsky – Rosen discovery of nonlocal correlations

nÏdr~mha Ordgï›r Amh H$m?

प्रो. जयंत नारळीकर

हा प्रश्न अनेकदा विचारला जातो. इतकेच नव्हे तर पृथ्वीवरील वेगवेगळ्या देशांतल्या विविध संस्कृतींमध्ये लोकांनी ह्या प्रश्नाला होकारांती उत्तर ही दिल्याचे दिसून येते. आपल्या पौराणिककथांमध्ये देव, दानव, यक्ष, किन्नर आदींचा उल्लेख असतो. तसेच उल्लेख इतरत्र ही पाहिले की वाटते मानवाला एक जिज्ञासाच नव्हे तर आकांक्षा आहे की आपल्याहून श्रेष्ठ योनी पृथ्वीबाहेर पसरलेल्या अंतराळात असाव्यात.

आजचे खगोल विज्ञान ह्या आकांक्षेला खतपाणी पुरवते. पृथ्वी सूर्याच्या ग्रहमालेचा एक ग्रह. आपल्या आकाशगंगेतल्या १००-२०० अब्य ताऱ्यांपैकी सूर्या सारखे अब्जावधी तारे सापडतील. १९९० पासून ताऱ्यांभोवती ग्रहमाला शोधण्याचे प्रयत्न सुरु झाले व त्यांना सफलता मिळू लागली. तेव्हा केवळ संख्येच्या दृष्टीने 'सूर्यासारख्या ताऱ्याभोवती पृथ्वी सारखा ग्रह' असण्याची शक्यता पुष्कळ आहे. इतकेच नव्हे तर जीवशास्त्राच्या दृष्टीने पृथ्वीवरील जीवसृष्टीच्या मुळाशी असणाऱ्या DNA रेणूचे घटकरेणू अंतराळात पसरलेल्या विशाल वायुमेघात सापडत आहेत. हे सर्व पाहता आपल्या आकाशगंगेत आपल्यापेक्षाही प्रगत जीव असण्याची शक्यता नाकारता येणार नाही. पण त्यांच्याशी संपर्क कसा साधायचा? Search for Extra-Terrestrail Intelligence (SETI) प्रकल्पासाठी असे प्रयत्न चालू आहेत. आकाशगंगेत आपल्यापासून १०-२० प्रकाशवर्षे अंतरावरील ताऱ्यांच्या दिशेने रेडिओ संदेश पाठवून तेथून काही उत्तर येते का हे पाहण्याचे प्रयत्न ह्या प्रकल्पाखाली चालू आहेत. तसेच अशा दोन 'उच्चसंस्कृती' परस्परांशी संभाषण चालू ठेवून आहेत का हे पाहण्यासाठी त्यांच्यातर्फे पाठवले जाणारे संदेश मधल्या मध्ये 'टॅप' करण्याचे प्रयत्न पण चालू आहेत. २१ सेंटीमीटरची लांबी असलेल्या लहरी प्रामुख्याने 'सेटी'साठी वापरतात. ह्या लहरी शोषणापासून बऱ्यापैकी मुक्त असून आकाशगंगेत लांबचे पल्ले गाठू शकतात. त्यांच्यामाध्यमातून पृथ्वी भोवतालच्या वायुमंडलात गोंगाटही कमीच आहे. ह्या दोन फायद्यांव्यतिरिक्त, २१ सें.मी. चा आणखी एक गुण म्हणजे तिचा हायड्रोजनच्या अणूच्या रचनेशी मूलभूत संबंध आहे. हायड्रोजन अणूच्या रचनेत स्वयंप्रेरित बदल घडवून त्यातून ह्या लांबीच्या लहरी निघतात. हायड्रोजन हा आकाशगंगेचा सर्वव्यापी घटक असल्याने ह्या लहरी आकाशगंगेत सगळीकडे पसरलेल्या आहेत व म्हणून दूरवरच्या जीवांना (अर्थात् प्रगत अवस्थेतील) त्यांचे गुणधर्म चांगले परिचित असणार. म्हणूनच अशा लहरींच्या माध्यमातून संदेश पाठवल्यास ते ग्रहण करायची 'सोय' त्यांच्याकडे असेल.

हे संदेश पाठवण्यासाठी विशाल रेडिओ ॲण्टेना (मोठ्या डिशच्या रुपात) उभारावे लागतात. रेडिओ खगोल विज्ञानासाठी अशा दुर्बिणी अस्तित्वात असल्याने त्यांचाच वापर केला जातो. सेटी साठी संदेश पाठवणे तसेच संदेश ग्रहण करणे दोन्हीची गरज असते. डिशवर येणाऱ्या 'गोंगाटात' खराखुरा माहितीचा सिग्नल आहे का नाहीं हे पहायला मिलियन चॅनल ॲनलायझर सारखे उपकरण संगणकाला जोडून वापरतात. दशलक्ष चॅनल पैकी नेमक्या कुठल्या चॅनलवर संदेश आहे. (-असला तर!) हे त्या उपकरणातून कळते. शिवाय हौशी सेटी प्रकल्पात भाग घेणारे पुष्कळ आहेत. त्यांच्याकडे दुर्बिणीतून आलेले रेकॉर्डिंग पाठवले जाते व त्यांना पुरवलेल्या सॉफ्टवेअरच्या मदतीने ते गोंगाटातून संदेश शोधतात.

अर्थात आपण पाठवलेला संदेश आणि 'त्यांनी' पाठवलेला संदेश इंग्रजीत किंवा पृथ्वीवरच्या इतर कुठल्या भाषेत असायची गरज नाही. हा संदेश विज्ञानाची (गणित + भौतिकशास्त्र + जीवशास्त्र + खगोल निरीक्षणे) सांकेतिक माहिती देणारा असावा. तो वाचून पाठवणारा अमुक एका स्तरापर्यंत विज्ञानाची प्रगती करु शकला आहे हे कळावे अशी अपेक्षा ! अजून असा संदेश बाहेरुन मिळालेला नाही. पृथ्वीकडून मात्र संभाव्य ताऱ्यांच्या दिशेने असे संदेश पाठवण्याचे काम गेली तीस वर्षे चालू आहे. सादाला प्रतिसाद मिळाला तर ती मानवी इतिहासातली सर्वात महत्त्वाची घटना ठरेल.

परंतु आपल्याहूनही प्रगत अशा जीवसृष्टीला शोधताना आपल्याला एका वेगळ्या शोधामागे देखील प्रगती करता येईल. हा शोध वेगळ्या दिशेने, सूक्ष्म जीवांना शोधण्याचा आहे. त्यामागची कल्पना अशी.

सुमारे तीस वर्षांपूर्वी ब्रिटनमधील दोन खगोलशास्त्रज्ञ, फ्रेड हॉएल आणि चंद्र विक्रमसिंधे यांनी अशी कल्पना मांडली की पृथ्वीवर जीवसृष्टीची निर्मिती झाली त्या मागे ओपॅरिन व हॉल्डेन ह्या शास्त्रज्ञांचा तर्क बरोबर नाही. ओपॅरिन-हॉल्डेन तर्काप्रमाणे

पृथ्वीची निर्मिती झाल्यावर सुरवातीच्या काळात पृथ्वीवरील वातावरण आजच्या पेक्षा वेगळे आणि पुष्कळ खळबळ जनक होते. त्या वेळी अमोनिया, मीथेन आणि पाण्याची वाफ यांचा विजांच्या उपस्थितीत संयोग होऊन अमीनो अम्ल तयार झाले. त्यातून पुढे डी.एन.ए व पुढे पेशी अशा क्रमाने जीवसृष्टीची सुरुवात झाली. थोडक्यात, ओपॅरिन-हॉल्डेन मताप्रमाणे पृथ्वीवरची जीवसृष्टी सर्वस्वी पृथ्वीवर तयार झाली. ह्या तर्काचे खंडन करताना हॉएल-विक्रमसिंघे यानी असे मत मांडले की पृथ्वीवर जीवसृष्टी चा विकास झाला तो मुळात तेथे बाहेरुन आलेल्या जीवाणू - विषाणू (बॅक्टेरिया-व्हायरस) तून.

हे सुक्ष्मजीव पृथ्वीवर आले कुठून ? हॉएल-विक्रमसिंघे यांचा असा दावा आहे की अंतराळात ताऱ्यांदरम्यान प्रदेशात ज्या प्रमाणे गॅस व धूलिकण आहेत त्याच प्रमाणे सूक्ष्म जीवाणू-विषाणू पण आहेत. दुरुन येणारे धूमकेतू त्यापैकी काहीना आपल्या भिजलेल्या वस्तूतून आणतात. सूर्याजवळ बाष्पीभवन होऊन शेपूट तयार झाली की हे धूमकेतूतले जीवाणू त्या शेपटीत पसरतात. शेपूट कधीकधी पृथ्वीच्या वायुमंडलाला घासून जाते. अशावेळी हे जीवाणू वायुमंडलात घुसतात व पृथ्वीच्या गुरुत्वाकर्षणामुळे पृथ्वीतलावर उतरतात.

ह्या तर्काला प्रस्थापित जीवशास्त्रज्ञांनी कडाडून विरोध केला किंवा त्याची थट्टा केली. कारण त्यांच्या मते पृथ्वीच्या वायुमंडलाच्या संरक्षणाबाहेर विश्वात क्ष किरणे, गामा किरणे, अल्ट्राव्हायोलेट प्रकाश आदींच्या माऱ्यात जीवाणू टिकून राहणे शक्य नाहीं. तेव्हा दुरुन असे जीवाणू इकडे सुखरुप येणे शक्यच नाहीं ! ह्या शिवाय एक असाही पूर्वग्रह वैज्ञानिकात सापडतो - जो कोपर्निकस नंतर ही दिसतो - की आपली पृथ्वी विश्वात विशेष स्थान ठेवून आहे. कदाचित् जीवसृष्टीपण पृथ्वीशिवाय इतरत्र नसेलच.

परंतु गेल्या काही वर्षात प्रयोगांती दिसून आले आहे की अशा तीव्र किरणांचा मारा केला तरी जीवाणू आपली अंतर्गत रचना बदलून प्रतिकार शक्ती वाढवतात आणि जगू शकतात. तेव्हा पूर्वग्रह न बाळगता आपण वरील सिद्धांत प्रयोगाने तपासू शकतो का ?

ह्या साठी काही वैज्ञानिकांच्या वतीने मी इंडियन स्पेसरिसर्च ऑर्गनायझेशन (इस्रो) कडे अर्ज केला की त्यानी अशा प्रयोगासाठी पैसा आणि ज्ञान पुरवावे. अंतराळात ३०-४० कि.मी. उंचीवर जाणारे फुगे सोडून त्यांना बांधलेल्या उपकरणात तेथील हवेचे नमूने गोळा करुन आणायचे काम इस्रोच्या तंत्रज्ञानी यशस्वीरीत्या केले होते - फक्त अशा नमुन्यांत धुळीचे कण, रेणू आदींची उपस्थिती शोधण्याचे काम त्या प्रयोगांत केले गेले होते. आम्हाला पहायचे होते की इतक्या उंचीवर आपल्याला जीवाणू सापडताहेत का. इस्रोचे त्यावेळेचे संचालक कस्तूरीरंगन यांनी उत्साहाने ह्यासाठी इस्रोचे पाठबळ आमच्या मागे उभे केले. टाटा इंस्टिट्यूट ऑफ फंडामेंटल रिसर्च च्या हैदराबाद येथील बलून फॅसिलिटी चा वापर करायचे आम्ही ठरवले व २००१ साली जानेवारी महिन्यात आम्ही पहिला प्रयोग यशस्वी केला. एका उपकरणात १६ स्टेनलेस स्टीलच्या नळ्या पूर्णपणे निर्वात व निर्जंतुक करुन झाकण लावून फुग्याला जोडून वर पाठवण्यात आल्या. पूर्व नियोजित उंचीच्या पट्ट्यात अमुक एक नळी उघडून क्रायोपंपाने त्यांत वायुमंडलाची हवा भरुन नळी बंद करायची त्यांत व्यवस्था होती. टेलीकमांड द्वारे हे सर्व जमिनीवरुन करता येते. त्या करिता आम्ही चार उंचीचे पट्टे निवडले - सुमारे २५, ३०, ३५ आणि ४१ कि. मी. उंचीचे. नंतर पॅराशूट द्वारे फुग्यापासून उपकरण सोडवून खाली उतरवले. एकंदर प्रयोगाला काही तास लागले.

आम्ही गोळा केलेले नमुने हैदराबाद येथील सेंटर फॉर सेल्युलर ॲण्ड मॉलेक्यूलर बायॉलॉजी व कार्डिफ येथे सेंटर फॉर ॲस्ट्रोबायॉलॉजी येथे तपासणी साठी पाठवले. गोळा केलेल्या हवेत जीवाणू, विषाणू आहेत का हे पहायचा उद्देश होता. कार्डिफ येथे विक्रमसिंघे यांच्या मार्गदर्शनाखाली तेथील जीवशास्त्रज्ञानी ज्या तपासण्या केल्या त्यांत त्यांना जिवंत पेशी आढळल्या. नळ्यांना चिकटलेला भाग खरडून काढल्यावर त्यांत शेफिल्ड येथील प्रयोगशाळेला जीवाणू (बॅक्टेरिया) सापडले. हैदराबाद च्या प्रयोग शाळेला पेशी सापडल्या नाहींत पण खरडलेल्या भागात जीवाणू सापडलेत.

आता प्रश्न असा येतो की ४१ कि.मी. उंचीवर सापडलेले जीवाणू किंवा पेशी तेथे आले कसे ? पृथ्वीवरुन इतक्या उंचीवर पोचायला ज्वालामुखीचे उद्रेक किंवा वातावरणातील वादळे सुद्धा अपुरी पडतात. ज्वालामुखीचे कण जाास्तित जास्त ३० कि.मी. पर्यंत पोचल्याचे माहीत आहे. तेव्हा आम्हाला सापडलेले 'सूक्ष्मजीव' खालून न येता वरुन आले असे गृहित धरायला जागा आहे. त्यातून हॉएल-विक्रमसिंघे यांच्या तर्काला पुष्टी मिळते. पण हा तर्क बराच खळबळजनक असल्याने त्याच्या तपासणी साठी अजून नव्या प्रयोगांची गरज आहे. २००५ साली आम्ही फुगा वर पाठवून नमुने गोळा केले. त्यांची तपासणी चालू आहे. योग्य वेळी त्यांचे निष्कर्ष जाहीर होतील.

Drake's equation:

$N = R * f_s * f_p * n_e * f_l * f_i * f_c * L$

R = Average rate of star formation (stars/year)

$\mathbf{f_s}$ = Fraction of stars that are 'good' *suns*

$\mathbf{f_p}$ = Fraction of good stars with planetary systems

n_e = Number planets per stars within ecoshell

$\mathbf{f_l}$ = Fraction of n_e on which life develop

$\mathbf{f_i}$ = Fraction of living species that develop intelligence

$\mathbf{f_e}$ = Fraction of intelligent species reaching an electromagnetic communicative phase

L = Lifetime in communicative phase (years)

The answer depends on estimates for the various factors made by individuals and varies between 1 and several billions! A middle opinion centres around a million or so.

N : L

The Extra-Terrestrial Intelligences;

How can we search for them?

By sending space-ships?

❖❖❖

Einstein on light :
from waves to quanta and back

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One of Einstein's famous 1905 papers is often referred to as his ''photoelectric effect paper''. Indeed the Nobel Prize he received was in 1921, for the same photoelectric formula. The physical arguments underlying the formula lay the foundation for a quantum theory of electromagnetic waves. Newton had suggested that light consisted of particles, however later discoveries had firmly established light as waves. Under the circumstances photons was a daring hypothesis.

With later developments culminating in the formulation of Quantum Electronics (more commonly known as laser technology), the subject of Nobel Prize 2005, we seem to have come a full circle, from particles to waves, back to particles. However there are profound differences between Newtonian concept of particles and the concept of photons proposed by Planck and Einstein. This subtle difference was brought out in S N Bose's derivation of Planck' raditaion formula.

The discovery of Planck's formula has an interesting history starting with Kirchoff's proposal and Planck's rather ''desperate'' hypothesis. In turn, Einstein's interest in the formula is kindled not by a desire to prove the photoelectric formula but as a point of principle regarding Statistical Mechanics. Einstein disagreed with the method followed by Boltzmann and Planck and established that ''common sense'' concepts suffice to obtain Planck formula however only if we admit the notion of light quanta applicable to more general setting than required by Planck formula. The photoelectric formula was proposed by way of verifying this hypothesis. The formula did not get experimentally verified until 1912. And nobody except Einstein himself seems to have believed in the photons until Bose's paper provided the simple but profoundly different counting procedure required for the states of electromagnetism we call photons.

Bose's derivation proves that while photons are discrete, they still are not like ordinary particles. Quanta as distinct from particles and as a novel physical concept never previously encountered has baffled a whole century of thinkers and caused people to suspect the completeness of the new science of Quantum Mechanics. With the arrival of the formulation of Glauber and Sudarshan, and as first proved by Sudarshan, there is complete mathematical equivalence for the description of electromagnetism between of the photon description according to quantum principles and the classical description as waves.

What was Einstein's disagreement with Boltzmann and Planck ? Is it justified in retrospect ? In what sense did this difference strengthen Einstein's bold initiative ? Why did one have to wait till 1924 for Bose to set the new initiative in right perspective ? Are we in possession of a logically complete description after the arrival of Quantum Electronics ? These are some of the questions which may be interest for further study.

Theory of Relativity - I
Time-keeping in Special Relativity

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Abstract

An elementary discussion is given of how time measurements differ for different inertial observers according to Einstein's special theory of relativity. A comparison is made with the Newtonian (pre-relativity) method of time measurement.

Introduction

In 1905 Einstein published three papers, each of which turned out to be a trend-setter. One was his discussion of the phenomenon of Brownian motion, another was on the photo-electric effect and the third introduced the special theory of relativity. This simple discussion presents a highlight of the special relativity, one which baffled and confused most people, including physicists, but which is factually borne out by experiments.

The principle of relativity of motion implies that two inertial observers 'see' the same basic physical laws. Here an inertial observer is one on whom no force acts. By Newton's first law of motion such an observer has uniform velocity. Thus two inertial observers will in general have a uniform *relative* velocity. And two such observers should find the same mathematical structure for all basic physical laws. In other words, the relative velocity plays no role in the fundamental formulation of physical laws.

So consider two inertial observers *A* and $\mathbf{A}'$ with $\mathbf{A}'$ having a uniform velocity **v** relative to *A*. Both conduct electromagnetic experiments in their labs, and discover (or, rather, rediscover !) Maxwell's equations. Suppose *A* writes the Maxwell equations in vacuum as

$$\nabla.\boldsymbol{B}=0, \qquad \nabla.\boldsymbol{E}=0, \qquad \nabla\times B-\frac{1}{c}\frac{\partial \boldsymbol{E}}{\partial t}=0, \qquad \nabla\times\boldsymbol{E}+\frac{1}{c}\frac{\partial \boldsymbol{B}}{\partial t}=0 \tag{1}$$

Here **E** is the electric field vector and **B** the magnetic field vector while *c* is a fundamental constant. (Note that in vacuum $B\equiv H$, $E\equiv D$ in the usual notation.) Given this and the principle of relativity, we can assert that $\mathbf{A}'$ will find *exactly the same set of equations connecting* his measured quantities E' and B' .

So far this seems reasonable. One could argue that there exists a linear transformation between (E, B) and (E', B') that preserves the form (1). However, let us use (1) for a little manipulation. Taking curl of the third equation of (1) and using the first and fourth ones, we get

$$0 \equiv \nabla\times\left[\nabla\times B-\frac{1}{c}\frac{\partial E}{\partial t}\right] \equiv \nabla(\nabla \bullet \mathrm{B}) - \nabla^2\mathrm{B} - \frac{1}{c}\nabla\times\frac{\partial E}{\partial t}$$

$$\equiv -\nabla^2\mathrm{B} - \frac{1}{c}\bullet\frac{\partial}{\partial t}(\nabla\times\mathrm{E})$$

$$\equiv -\nabla^2\mathrm{B} + \frac{1}{c^2}\frac{\partial^2\mathrm{B}}{\partial t^2}$$

(2)

Likewise we also get

$$\nabla^2\mathrm{E} - \frac{1}{c^2}\frac{\partial^2\mathrm{E}}{\partial t^2} = 0 \qquad (3)$$

Both the equations (2) and (3) are wave equations and they tell us that **E** as well as **B** propagate with a fundamental speed *c*. What is this constant *c* ? Experiments identify it with the speed of light in vacuum. Thus, working in their respective labs both A and $\mathbf{A}'$ will conclude that any light wave they see must travel with speed *c*.

This conclusion drawn from a reasonable looking basic principle appears counter-intuitive to anyone accustomed to thinking in the Newtonian way. For, if *A* sees an object *C* coming with velocity **u**, then $\mathbf{A}'$ should find its velocity as **u-v.** And this result applied to a light wave would tell us that *A* and $\mathbf{A}'$ would find different values for their measurements of the speed of light.

So, we have two possibilities open to us. Either we carry on with Maxwell's equations *as they are* and Newton-based system of spacetime measurements or we *revise* Maxwell's equations so that the above discrepancy is removed. Einstein opted for the first recourse and was led to the special theory of relativity.

Transformations between inertial frames

Briefly, we may denote the two possibilities above by the *Galilean and Lorentz transformations* between the spacetime coordinates of an event masured by A and $\mathbf{A}'$. Let us consider the Galilean transformation first. It is given by

$$\mathrm{X}' = \mathrm{X} - vt, \qquad t' = t \qquad (4)$$

Here we have *no change of time coordinates,* while the space coordinate suffers a translational change. This transformation gives expression to the Newtonian concepts of absolute space and absolute time. Note that, although the spatial coordinates change, the spatial separations between two events occuring at the same time do not. Also, accelerations do not change.

$$\frac{\mathrm{d}^2\mathrm{X}'}{dt'^2} = \frac{\mathrm{d}^2\mathrm{X}}{dt^2}; \qquad (5)$$

so that Newton's second law of motion remains unchanged. But, as we saw earlier, Maxwell's equations cannot retain the same form under the Galilean transformation.

The second alternative of Lorentz transformation looks, at first sight, very messy. Corresponding to (4) we have

$$(\mathrm{x}' \cdot v) = \gamma(\mathrm{x} - vt) \cdot v$$

$$\mathrm{x}' \times \mathrm{v} = \mathrm{x} \times \mathrm{v},$$

$$t' = \gamma\left(t - \frac{\mathrm{v}.\mathrm{x}}{c^2}\right), \tag{6}$$

where

$$\gamma = \frac{1}{\sqrt{1 - \frac{v2}{c^2}}} \tag{7}$$

This transformation leaves the components of space coordinates normal to v unchanged, but alters the longitudinal spatial component (parallel to v) and *also the time coordinate.* Because of the factor y, the displacement in space (or time) of two events at the same time (or space) is not the same, but is multiplied by the factor . Note, however, that a little algebra applied to the equations (6) will lead to the result

$$c^2t^2 - x'^2 \equiv c^2t^2 - x^2 \tag{8}$$

Thus if a light wave propagated along $|\mathrm{x}| = ct$ as seen by A, it will be seen by A' as propagating along $|\mathrm{x}'| = ct'$, i.e., with the same speed *c*.

A practical example

In case the above discussion appears too pedantic here is a simple example, which I first came across in a public lecture given by Hermann Bondi.

We consider two observers A and $\mathbf{A}'$ separating out with a uniform speed v. We count times t, t' as measured by A and $\mathbf{A}'$ from the instant they were together. Thus we have $t = t' = 0$ at that instant. The tracks of A and $\mathbf{A}'$ in space-time diagram are shown in the Figure 1.

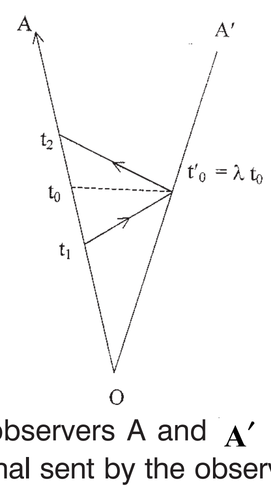

Figure 1 : The tracks of observers A and $\mathbf{A}'$ are shown in the spacetime diagram as diverging from point 0. A light signal sent by the observer A (by his watch) at time t_1 is received by A' (by his watch) at time t'_0. Refer to the text for details.

To have a practical measurement of each other's time coordinates, A and $\mathbf{A}'$ send out light signals towards each other. Suppose A sends a signal at time $t_1 > 0$ by his watch. When $\mathbf{A}'$ receives it, at his measured time t'_0, say, he sends back a reply light signal immediately, reaching A at his recorded time t_2. However, A estimates from his timings that $\mathbf{A}'$s would have received his signal at

$$t_o = \frac{1}{2}(t_1 + t_2) \tag{9}$$

as measured by his (A's) watch. Let us assume that

$$t' = \lambda t_o \tag{10}$$

In the Newtonian (Galilean) system we would expect $\lambda = 1$.

However, in the special relativistic system, the speed of light is *c* for both the signals sent out by A and $\mathbf{A}'$. So we have the distance of $\mathbf{A}'$ from A at the time to (or t'_o as measured by $\mathbf{A}'$) as d, where

$$2d = c(t_2 - t_1). \tag{11}$$

Now A estimates that travelling with velocity ν away from him for a time, $\mathbf{A}'$ would have moved to a distance.

$$d = vt_o = \frac{(t_1 + t_2)}{2} \times v \tag{12}$$

From (11) and (12) therefore we get

$$\frac{v}{c} = \frac{t_2 - t_1}{t_1 + t_2}. \tag{13}$$

So far we have not used the principle of relativity fully. We do so now. Consider the light ray sent by A at t_1 which reached $\mathbf{A}'$ at t'_0. Suppose we write,

$$t'_o = \alpha t_1. \tag{14}$$

By similarity of geometrical shapes and the reciprocity between the observers, a typical signal sent out by A at *any* instant t_1 would reach $\mathbf{A}'$ at time αt_1 as measured by the watch of $\mathbf{A}'$, *with the same α, and vice versa*. That is, the signal sent by $\mathbf{A}'$ at t'_o would reach A at time $\alpha t'_o$ as measured by A. We thus have

$$t_2 = \alpha\, t'_o = \alpha^2 t_1. \tag{15}$$

From (13) and (15) we therefore get

$$\alpha = \left(\frac{1 + \frac{v}{c}}{1 - \frac{v}{c}} \right)^{\frac{1}{2}} \tag{16}$$

How do we compare the time measurements by *A* and A' ? Suppose *A* has stationed another colleague *B* at rest relative to him but located at the point where A' will be when the signal from *A* reaches him, that is, at time by the watches *A* and *B* (which are supposed to be synchronized). So as A' passes him, B will record that the watch carried by A' showed the time t'_o. How does to compare with his own time t_o? Using (9) and (15) we get

$$t_0 = \frac{1}{2}\left(\alpha^2 + 1\right)t_1,\ t'_0 = \alpha t_1 \Rightarrow \frac{t'_0}{t_0} = \frac{2\alpha}{\alpha^2 + 1} \qquad (17)$$

Using (16) for α we get for λ as defined in (10),

$$\lambda \equiv \frac{t'_0}{t_0} = \sqrt{1 - \frac{v^2}{c^2}} = \gamma^{-1} \qquad (18)$$

Thus $\lambda \neq 1$ as expected by the Galilean transformation. Rather we have $\lambda < 1$. To *B* it would appear that the watch carried by A' as he moves past is running slow.

Let us recall the reciprocity of the two observers. In fact if we interchanged the roles of A and A' and let A' bounce a light signal off A, his colleague B would come to the conclusion that the watch carried by A is going slow !

Conclusion

There was considerable discussion in the early days of relativity, whether time dilatation or slowing down of time implied a logical contradiction. 'If the watch of A' goes slower than the watch of A by factor λ and *vice versa,* surely the two conclusions cannot both be right. So special relativity must be wrong !'' This was the argument made by the opponents of special relativity.

This conclusion is, however, logically erroneous. For, in the first experiment the slowness of the watch of A' was detected by two observers A and B at rest relative to each other and located at different points of the trajectory followed by A' . In the second experiment A' and B' together measured and compared the times kept by their watches with the watch of A. So the two experiments were not the same and there was no contradiction between their differing conclusions. In fact the result underscores the symmetry or reciprocity of any two inertial observers.

The decay of the μ - meson (now commonly known as muon), a particle present in cosmic rays, established that the result of time dilatation is factually correct. Typically, a muon in its own frame of reference decays with a half life of ~ 1.5 x 10^{-6} second. Cosmic rays take longer than this to travel to the Earth.In fact if we compare the number of muons that actually reach the sea level, with the number of particles expected to survive, we find that there are far too many muons reaching the sea level. This phenomenon is explained by the relation (18). In the rest frame of the muon, the time runs slower compared to the Earth-bound observer's frame, with $\lambda \approx 1/9$. This makes it possible for the muons to have survived.

Theory of Relativity - II
Faster-than-light Motion

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Abstract

This talk describes the notion of *tachyons* in special theory of relativity. It argues that despite the limit placed on the speed of material particles by the theory of relativity, it is possible to imagine a class of particles which *always* travel faster than light. Simple dynamical concepts like energy and momentum are defined for such particles and causality problems arising from their presence are discussed. A causality paradox is presented at the end.

Introduction

Let me begin with a limerick by Reginald Buller that became quite well known in the early days of relativity; it was first published in the British magazine *Punch* on December 19, 1923 :

There was a young lady named Miss Bright.
Whose speed was far faster than light.
She set out one day
In a relative way
And returned on the previous night

The somewhat strange future in store for Miss Bright was speculated upon because the special theory of relativity appeared to place a speed limit on the speed with which any material object or a physical interaction, or indeed information per se can travel. The limerick voices the questions that many people, including physicists asked when they were confronted with the bewildering rules about space-time transformations between moving observers.

In particular we may phrase those questions as follows :

Does special relativity forbid faster-than-light motion ?

Does such a motion lead to violation of causality ?

Could we imagine a universe in which *some* particles travelling faster than light do exist?

In this lecture I will try to answer these questions within the framework of the special theory of relativity. These basic ideas were first discussed by George Sudarshan and his colleagues in 1962.

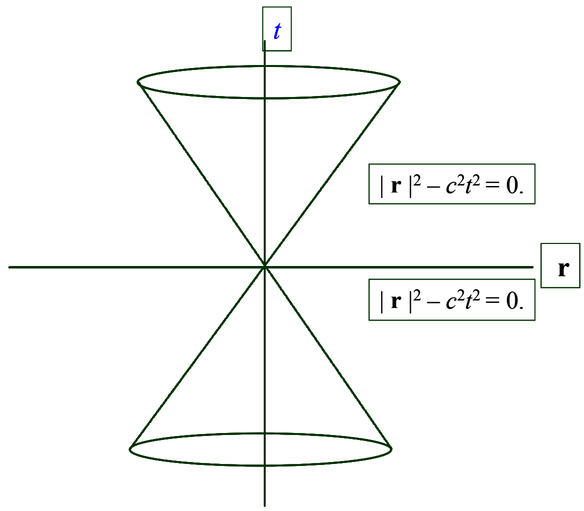
Three kinds of particles

Indeed, three kinds of trajectories can be identified within the framework of special relativity, given the key role that the speed of light c plays in it. I will use the time coordinate as t and the space coordinates as the triplet r = (x,y,z).

(I) Light travels along *null* trajectories. This means that a particle travelling with uniform speed equal to the speed of light, from the space-time origin will follow the path

$$|r|^2 - c^2t^2 = 0$$

$$|\mathbf{r}|^2 - c^2t^2 = 0.$$



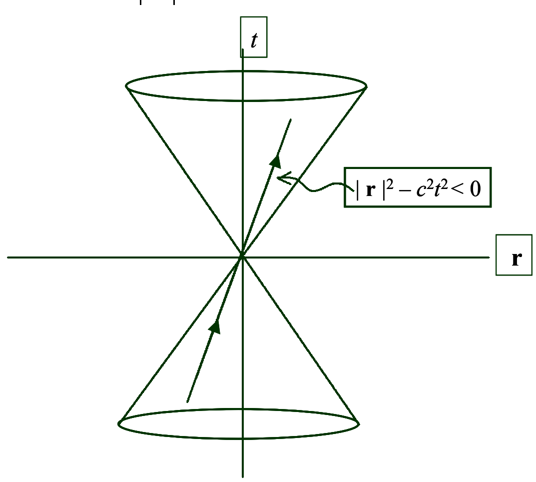
I) Light travel along *null* trajectories

This is a typical generator of a hypercone with vertex at the origin. This cone is called the *light cone.* The light cone can extend into the future (the *future* light cone) as well as into the past (the *past* light cone).

(II) Material particles travel along *time-like* trajectories. A typical path for such a particle will satisfy the inequality

$$|r|^2 - c^2t^2 < 0$$

$$|\mathbf{r}|^2 - c^2t^2 < 0.$$



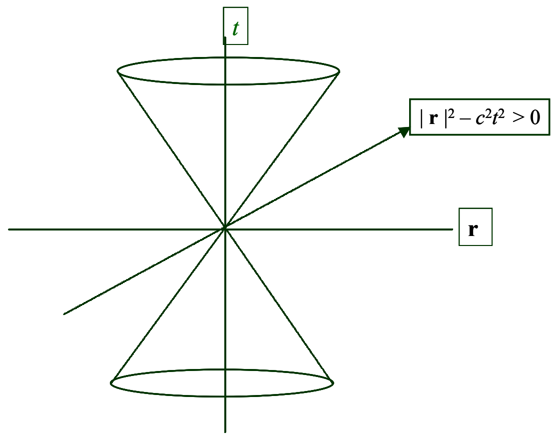
II) Material particles travel along *time-like* trajectories.

In other words, trajectories of material particles always lie *inside* the light cone. This is the quantitative statement of the fact that no material particle can travel with speed equal to or more than the speed of light.

(III) Faster than light motion, if it exists, would be along *space-like* trajectories. In our notation this will satisfy the inequality

$$|r|^2 - c^2t^2 > 0$$

$|\mathbf{r}|^2 - c^2t^2 > 0.$



(III) Faster than light motion would be along *space-like* trajectories.

which means that these trajectories will lie *outside* the light cone.

We may call Type (I) particles *luxons* and their examples are the photon, and the neutrino, assuming that it is not massive. The Type (II) particles are named *tardyons* or bradyons and their example is any material particle with mass, like an electron, a piece of chalk or an elephant ... The Type (III) particles are called *tachyons.* As yet no particle in this class has been found. So our first question can be rephrased: Can tachyons be considered physically realistic ? We begin our reply by familiarising ourselves with the concepts of energy and momentum of such particles.

The concepts of mass and energy

For a *tardyon* moving with velocity **v** (with magnitude v), the 'moving' mass is given by

$$m(v) = m_0\gamma,$$

where m_0 is called the rest mass of the particles and the factor γ is given by the velocity dependent expression

$$\gamma = \left[1 - v^2/c^2\right]^{-1/2}$$

For such particles the energy and momentum are defined by

$$E = m(v)c^2,\ \mathbf{P} = m(v)\mathbf{v}$$

Therefore, we have the simple relation between the energy and momentum

$$E^2 - |P|^2 c^2 = [m(v)]^2 \{c^2 - v^2\} c^2 = m^2{}_0 c4.$$

Why is the light-speed an unreachable barrier for tardyons ? Now we can see the reason. For, as the magnitude of the velocity, *v* tends to *c*, the energy and momentum of the tardyon tends to infinity. In short, *infinite force is needed to take \ P \ to infinity.* So there is a practical physical reason why a tardyon cannot attain the speed of light.

For a *luxon,* the speed is always c. The relations for a tardyon

$$E = m[v]c^2,\ P = m(v)$$

now change to

$$E = |P|c \ \text{ for } \ |v| = c.$$

So the relation between energy and momentum changes to

$$E^2 - |\mathbf{P}|^2 c^2 \equiv m^2{}_0 c^4 = 0.$$

This seems to suggest that the rest mass of a luxon is zero. However, such a statement, often made in literature is technically wrong. For, to be able to define a rest mass for a luxon, one must bring it to rest : and a luxon having always the speed of light, *can never come to rest.* So the above statement describes a limiting conditions that is never attained.

Consider now the tachyons for whom v = I **v** I > *c*. So *m(v)* is imaginary if m_0 were real. But again, for a tachyon 'rest mass' has no meaning for it always travels faster than light ! However, we can still let algebra guide us ! Let $m_o = i\, M_o$. Then we have

$$E = M(v)c^2,\ \mathbf{P} = M(v)\mathbf{v}.$$

where we have redefined mass of such a particle by

$$M(v) = M_0 \left[v^2/c^2 - 1\right]^{-1/2}$$

Notice that this relation is algebraically the same as for tardyons. The only difference is that because we now have *v>c,* we have redefined the mass. The mass m_0 in terms of our original definition was imaginary; but in terms of the new definition, the parameter M_o is real. It is called the *meta-mass* of the tachyon.

The new expression for energy *decreases* as the velocity v increases. Thus a tachyon *loses* energy as it moves faster and *gains* it as it slows down ! If it were to slow down to the speed of light, *E* would be infinite. Thus we have a physical reason why a tachyon can never slow down to attain the speed of light. So in principle, the special theory of relativity allows the three classes of particles to exist but with no interchange amongst them.

We also notice that for a tachyon the magnitude of the momentum multiplied by *c* exceeds the energy. This is the reverse of the rule for the momentum of the tardyon. Further, since the trajectory of a tachyon lies outside the light cone of its source (the origin in our example), it is possible for it to arrive at the receiver *before* it was emitted. In such a case the energy of the tachyon as defined above can be *negative*. Thus we imagine the energy to be decreasing from very large positive values for a tachyonic speed increasing from a little over *c* to infinite, and then turning negative as the tachyon moves into the past. As its speed into the past decreases from infinity to *c*, its energy remains negative but increases in magnitude from zero to infinity. Does a tachyon trajectory going into the past, affect adversely the principle of causality ? We shall address this question next.

Exchange of energy through tachyons

Imagine first, a physical interaction between two material particles (tardyons) in which a tacyhyon is exchanged. Suppose we have an inertial frame of reference in which the tachyon travels with *infinite* speed. Such a tachyon will have *zero* energy and so will not affect the energies of the source particle or the receiver particle. But if the tachyon were travelling into the past, what happens ? The source particle *gains* energy and the receiver particle loses it. This is because the tachyon is carrying negative energy. To deal with such scenarios, one has the so-called reinterpretation principle :

Reinterpretation Principle : A negative energy tachyon moving backward in time is equivalent to a postive energy tachyon moving forward in time.

Thus if the tachyon trajectory connects two points, A on the world line of a material particle a , and *B* on the world line of a material particle *b*, and if in a given inertial frame the time of *A* is later than the time of *B*, we say that the emitter is at *B* and the receiver is at A. These roles will be interchanged in another inertial frame in which the time coordinate of the world point *B* is later than that of the world point *A*. In other words, the effective exchange of energy always proceeds in the forward time direction. And since information transfer is also linked with energy transfer, we can state that there is no breakdown of causality with the use of the reinterpretation principle.

Can tachyons be relevant to physical rality ? Just as photons (which are luxons) act as exchange agents of energy between electrons, and pions (which are bradyons) are exchanged in nuclear processes, so are tachyons in principle exchangable in physical processes. So far no example of this has been found but tachyonic modes have been proposed for certain high energy particle interactions. Regardless of theory, tachyons should be empirically looked for in high energy cosmic rays.

Back to Miss Bright

Let us look at the travel of Miss Bright of the limerick. Consider two inertial observers O_1 and O_2 using respectively, reference frames $\sum_1$ and $\sum_2$, linked with the Lorentz transformation :

$$x_2 = \gamma \times [x_1 - vt_1],\ t_2 = \gamma \times \left[t_1 - vx_1 / c^2\right],$$

where the factor γ is related to the relative velocity between the two frames, v, by the relation mentioned earlier. Now suppose that Miss Bright follows a trajectory in frame $\sum_1$ given by

$$x_1 - ut_1 = 0.$$

Here we can say that Miss Bright left the origin at $t_1 = 0$ and was at $x_1 = uT_1$ at $t_1 = T_1$. Call this the destination point for Miss Bright. Thus the observer O_1 sees her going forward in time from the origin to the destination. However, the observer 0_2 at rest in Σ_2, will discover that Miss Bright reached that point at time.

$$t_2 = \gamma \times \left[T_1 - vx_1 / c^2\right] = \gamma \times T_1 \times \left[1 - vu / c^2\right] < 0$$

provided, Miss Bright was travelling with a velocity $u > c^2 / v > c$. In other words, to the second inertial observer, Miss bright appears to arrive at the destination point *before* she started from the origin.

This demonstrates the fact that time ordering is not absolute so far as tachyonic events are concerned. Thus in the above example the first observer sees Miss Bright leave the origin and arrive at the destination point later than her start, whereas the second observer sees her arrive at the destination earlier than when she started. The second observer can use the reinterpretation principle to argue that Miss Bright travelled from the destination point towards the origin ! In this way, any onflict with causality can be avoided.

A paradox involving tachyons

Nevertheless, as the above example shows, there can be odd effects wherever tachyons are mediating events. David Atkinson has come up with a nice space-time paradox involving tachyonic messaging which he has worded in terms of the Hindu mythology. I end this talk with that paradox.

A Tachyonic Chronoclasm

In Mount Meru airport there are two parallel travelators, a gigaparsec apart, travelling at the same speed in the same direction. One fine kalpa, Lakshmi, who had just bought a tachyonic transceiver at the airport shop, was standing on travelator number one, while Vishnu, admiring holographs of his future avatars, lounged by the art print counter. About 3 x 10^9 light years aways, a similar scene could be discerned through a Wheeler worm-hole: Parvati was unpacking her transceiver, on travelator number two, while Shiva, wetting his hair at the Ganga fountain, watched his shakti rush past. At this moment, Shiva began to dance, causing a big bang, followed by the grand unification *group* $SU(3) \times SU(2)_L \times U(1) \rightarrow SU(2)_L \times U(1) \rightarrow U(1)$ Parvati, noticing this, sent a tachyonic message to Lakshmi : ‘‘Shiva has broken extended conformal supergravity again.’’ After a few nanoseconds, Lakshmi received this portentous news and, since she was just whizzing past Vishnu, said : ‘Lord Shiva is dancing,” Vishnu had some trouble switching on his transmitter, but after three shakes of Garuda’s tail, he sent the tachyonic message: “Shiva, it’s time to dance.” On receipt of this instruction, Shiva danced, dances or will dance.

What is the sequence of events that actually took place ?

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Einstein's Theory of Special Relativity : Is it for ever ?

C. S. Unnikrishnan
TIFR, Mumbai

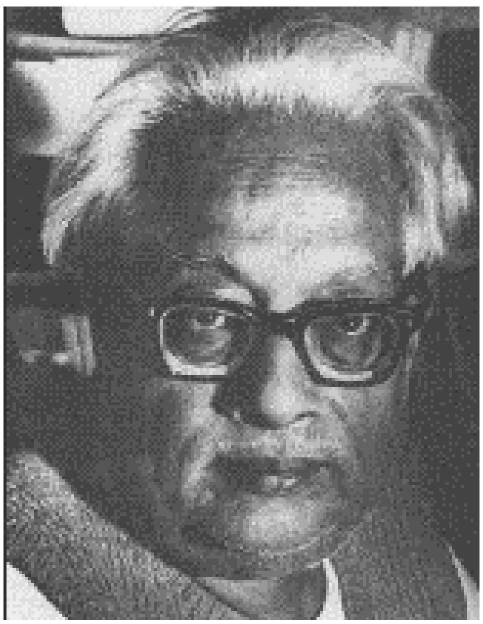
Synopsis : Einstein's wide-ranging works published in 1905 are being celebrated this year as the jewels of physicists' creations, marking the world year of physics. Particularly important and striking among these works is the theory of special relativity that forms a foundation for physical theories of particles, interactions and dynamics. The gist of special relativity is that there are no privileged frames of observers and that all observers are equivalent. In particular every observer in uniform motion can claim a state of rest and there is no way to distinguish between a state of rest and state of uniform inertial motion. The theory abolished the concept of 'Ether'. The physical consequences include the well known time dilation, length contraction, equivalence of mass and energy etc. What is important in this theory is that all physical effects depend only on the relative velocity between observers and there is a theory that is strictly valid only in empty space.

The theory of special relativity was created when there was no observational or theoretical cosmology of the vast universe that came to be known only in the past 40 or 50 years. Now we know that there are vast amounts matter surrounding us, and that there are ways of precisely determining our motion relative to the uniform microwave background radiation in the universe. Does the new knowledge of cosmology that provides a notional preferred frame to define absolute velocity and absolute time make Einstein's most studied and celebrated creation - special relativity - invalid ? If it did, that would be a shocking surprise with far reaching consequences to physics and natural philosophy.

In the talk, I will re-examine the theory of special relativity from a logically tight viewpoint, in the light of new cosmology. It turns out that the vast amounts of matter in galaxies and other forms affect time and space in a way that was not realized in 1905, or even later. It turns out that the physical effects observed in various experiments, and thought to be due to motion relative to each other are actually the gravitational effects of the matter in the universe. It is as if the matter filled universe has taken the role of the 'Ether'. Universe acts as a preferred frame, and physical effects actually depend on motion relative to the preferred frame of the universe (absolute motion) and not on just relative velocity between observers. In particular a transported clock can run faster than a stationary clock in some situations, contradicting the famous Einstein prediction of 1905 !

The totality of experimental evidence and logical consistency are thus against the fundamental theory of special relativity that we are celebrating today. Einstein's wonderful creation of 1905 had a good life of almost 100 years, but it has to be replaced by a new theory that acknowledges the gravity of the galaxies and other matter in the universe. The changes in time and space depend on absolute motion and are due to the gravitational influence of the entire universe. Mass is still equivalent to energy, but it is related to cosmology. Even the velocity of light is controlled by the gravity of the universe. Special relativity is not consistent with the fact that space is not empty. A theory of 'Cosmic Relativity' will replace 'Special Relativity', like the heliocentric theory replaced the earth-centric theory of the solar system. History teaches us that this paradigm change will be slow because of our tendency to adhere to old beliefs, but the change is inevitable with the realisation of the presence of the 'once given' matter filled universe.

- Atoms – Fluctuations and Brownian motion
- Light Quanta – photoelectric effect, spectrum, emission and absorption…
- Special Theory of Relativity
- Atoms and Light – 'Statistics', Bose-Einstein Condensation
- Equivalence Principle, Theory of Gravitation, General Theory of Relativity
- Foundational aspects of quantum theory – the E P R result and absence of action-at-a-distance (locality)



Physics Department Dacca University Dt. 4th June, 1924

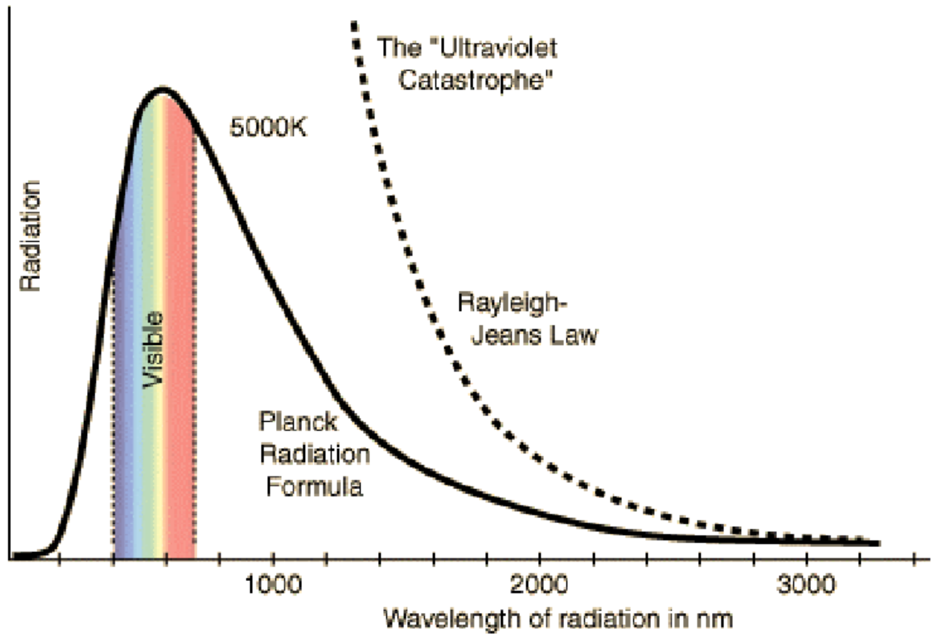
Respected Master,

I have ventured to send you the accompanying article for your persual and opinion. I am anxious to know what you think of it. You will see that I have tried to deduct the co-efficient $\frac{8\pi\nu^2}{c^3}$ in Planck's law independent of the classical electrodynamics only assuming that the ultimate elementary regions in the Phase space has the content h^3. I do not know sufficient German to translate the paper. If you think the paper worth publication, I shall be grateful if you arrange for its publication in Zeitschrift fuer Physik. Though a complete stranger to you, I do not feel any hesitation in making such a request. Because we are all your pupils…

Yours faithfully,

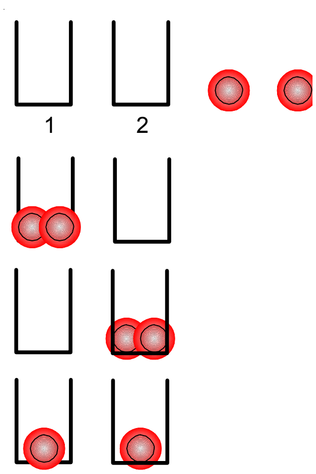
S N Bose

$$\rho(\nu,T)=\frac{8\pi\nu^2}{c^3}\frac{h\nu}{\exp(h\nu/kT)-1}$$



Bose’s derivation of the Planck law

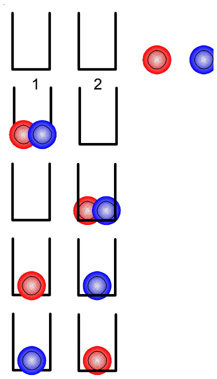
1. Photons are indistinguishable particles with momentum $h\nu/c$ (Quantum gas)
2. Any number of photons can be in the same state (identical properties like energy, momentum, polarization…)



a) Indistinguishable

b) Any number in same state

Probability of both particles in the same state =2/3



a) Distinguishable

b) Any number in same state

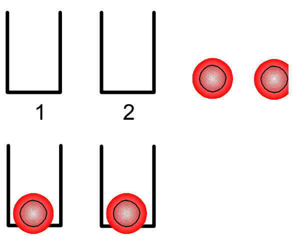
Classical statistics

Probability of both particles in the same state =2/4=1/2

This is far less than in the case for Bosons !

Thus bosons tend to occupy the lowest state much before reaching zero temperature

Bose condensation, Superfluid, Superconductor…



a) Indistinguishable

b) Only one in each state

Fermi-Dirac Statistics:

Only one particle in each state

Prob. of both particles in the same state = 0

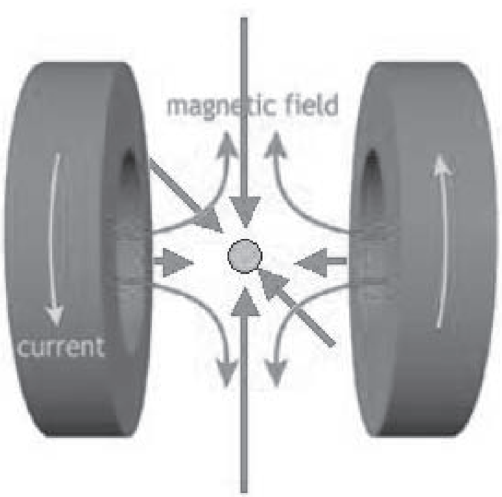
Many aspect of solid state physics, White dwarf, Neutron star…

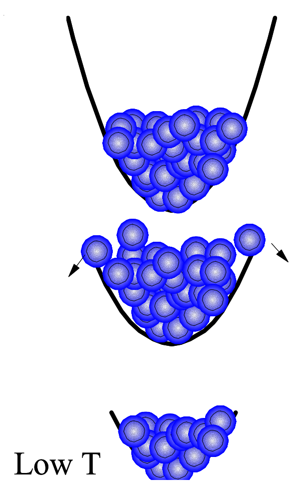
Einstein to Ehrenfest:

'From a certain temperature onwards molecules "condense" without attractive forces, that is, they accumulate at zero velocity. The theory is pretty, but is there also some truth to it?'

Bose-Einstein condensation of neutral atomic gas

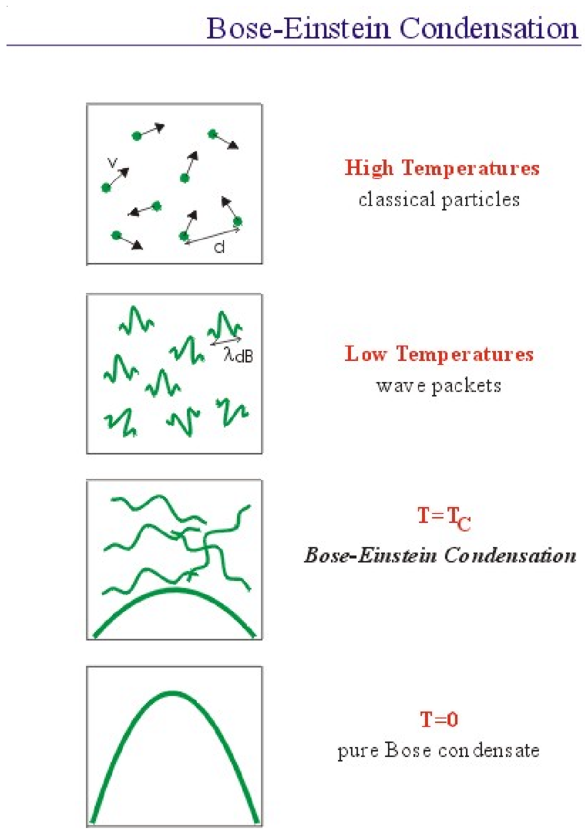
Magneto-Optical Traps





Evaporative Cooling

The BEC Phase Transition 3D



Bosons: Integer spin 'particles'

Fermions: Fractional spin 'particles'

Spin – Statistics Connection

"It appears to be one of the few places in physics where there is a rule that can be stated very simply, but for which no one has found a simple and easy explanation…This probably means that we do not have a complete understanding of the fundamental principle involved."

R. P. Feynman, FLP III

Perhaps we are forgetting something that is equally simple and obvious…

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HAVE YOU THOUGHT ABOUT THE UNIVERSE TODAY?

An Overview of Cosmology

Before 1915 : No extra-galactic cosmology

Largely milky-way + few novae + emptiness

1915 – 1925 : General Theory of Relativity, Large telescopes…

1925 – 1960 : Hubble law, Theoretical Universes, big- bang, expansion …

1960 – 2004 : Microwave background, Hubble telescope, precision cosmology…

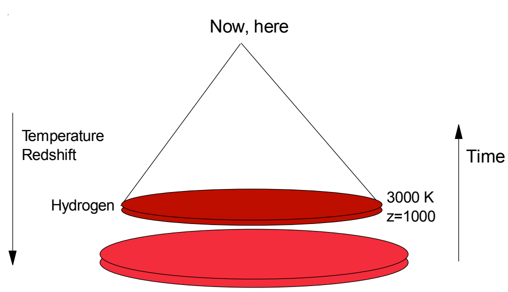
Cosmology:

The basis is General theory of Relativity and Einstein's equations

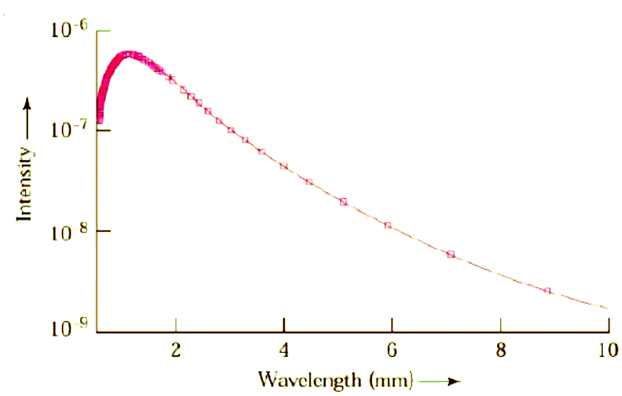
General features that are observationally supported:

- The Universe is expanding at the rate of $2x10^{-18}$ m/s/m
- The density of the Universe is about $2x10^{-29}$ g/cm^3
- There is a background radiation with the black body spectrum at the temperature of 2.728 K
- The Universe is approximately isotropic and homogeneous at very large scales

The Cosmic Microwave Background Radiation



The Cosmic Microwave Background Radiation



Why is this a “problem” ?

“The gist of the principle of relativity is the following. It is not possible to detect the motion of a body relative to empty space; in fact, there is absolutely no physical sense in speaking about such motion. If, therefore, two observers move with uniform but different velocities, then each of the two with the same right may assert that with respect to empty space he is at rest, and there are no physical methods of measurement enabling us to decide in favour of one or the other”.

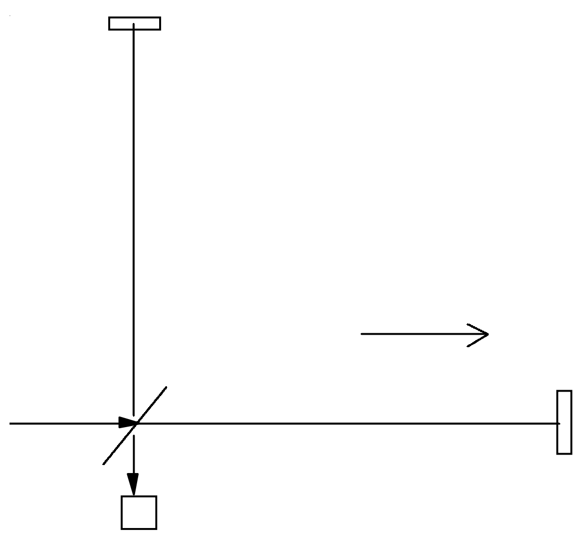
M. Planck, 1909

This situation is no longer true – space is never empty and there are markers for motion

Is it logically and physically consistent to work with a theory meant for empty space, in real universe filled with matter, energy and fields (discovered much later than 1905) ?

Velocity of Light and Ether

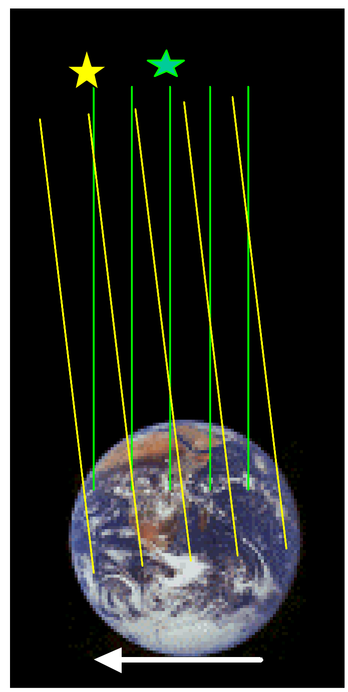
- Michelson-Morley Experiment
- Fizeau Experiment
- Aberration



Ether + Real Lorentz contraction

and Time dilation

All velocities are w.r.t Ether (absolute)



Empty Space + Lorentz transformations (relative)

All velocities are relative

1904-1905

Ether + Real Lorentz contraction
and Time dilation
All velocities are w.r.t Ether (absolute)

Empty Space + Lorentz transformations (relative)
Only relative velocities have physical significance

Special Theory of Relativity

- No preferred frame
- All observable physical effects depend only on relative velocities
- In particular, a transported clock will always run slower than a clock that remained stationary in the same frame (The 'velocity' of the frame is not important)

"If one of two synchronous clocks at A is moved in a closed curve with constant velocity until it returns to A, the journey lasting t seconds, then by the clock that has remained at rest the travelled clock on its arrival at A will be $\frac{1}{2}$ $\mathbf{tv^2/c^2}$ second slow"

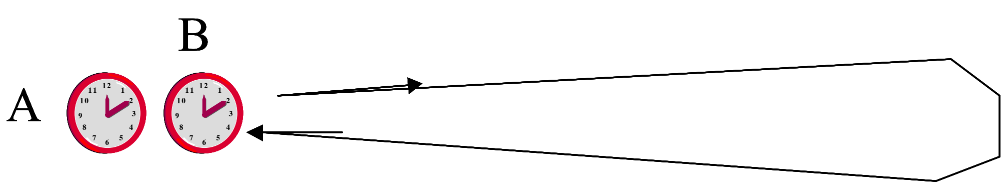
A. Einstein, 1905

WHY does one clock go slower?

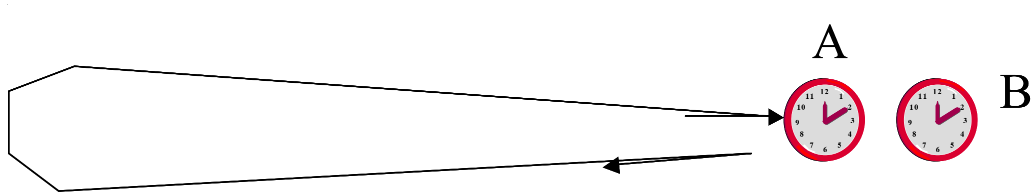
Since each clock can be considered as at rest in its frame, which clock REALLY ages less?

(It is experimentally known that acceleration does not affect the rate of the (atomic) clocks – only velocities are important)

Usual statement :



A: B goes at velocity v for time T, very brief reversal, and then comes back at v for time T. Total time dilation is approximately $-2Tv^2/2c^2$. B ages less than me.



B : A goes at velocity v for time T', very brief reversal, and then comes back at v for time T'. Total time dilation is approximately $-2T'v^2/2c^2$. A ages less than me.

I did feel some force, while at rest, for a brief period.

Important: A's estimate explicitly assumes that acceleration does nothing to either clock. So, if both A and B use the same physical laws, acceleration should be irrelevant (Einstein, 1911, 1914…)

Some comments at this points :

Acceleration by itself does not generate time dilation, and proper time is not affected by acceleration

Muons in storage ring at an acceleration of 10^{14} cm/s^2 have the same time dilation as muons traveling in straight line at the same velocity, for the same duration.

Note that there are SEVERAL "resolutions" of the twin clock problem in text books and physics literature, using different physical and logical reasoning:

A sure sign of confusion…

Einstein's resolution of the twin paradox in 1918

- Einstein, *Naturewissenschaften* **6**, 697 (1918)

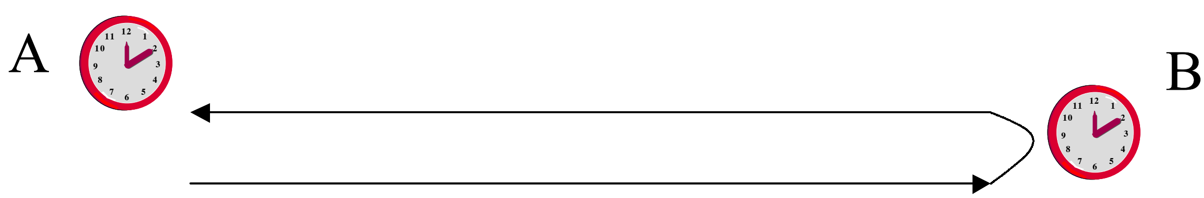
'Dialogue about objections to the Theory of Relativity'

Einstein was severely criticized in Germany for the clock paradox in special relativity…and finally he wrote a paper in 1918…

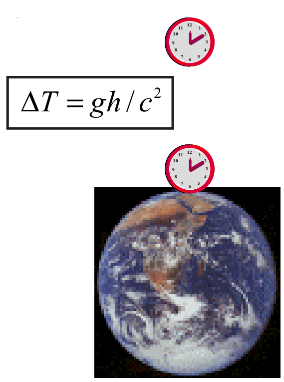
Einstein's resolution of the twin paradox in 1918

A. Einstein, *Naturewissenschaften* **6**, 697 (1918)

'Dialogue about objections to the Theory of Relativity'



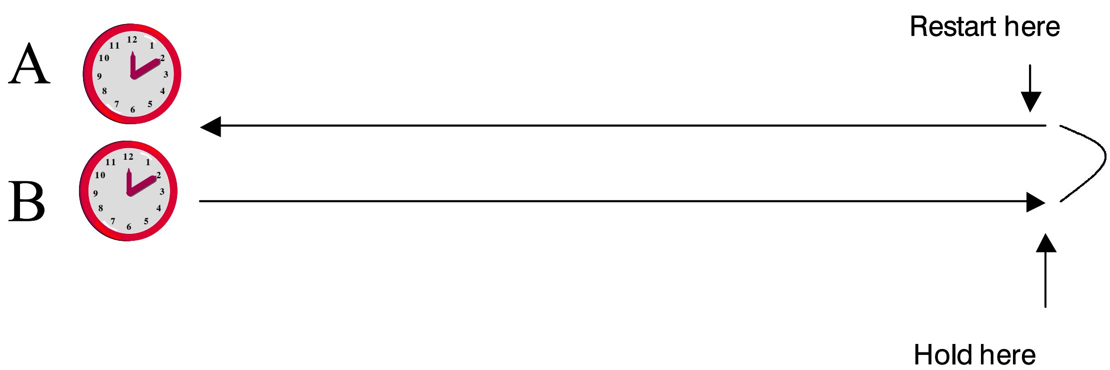
If two clocks are placed in DIFFERENT gravitational potentials, their rates and hence the accumulated time will be different.



Gravitational time dilation (GR)

Counter example :

Freeze the clock reading whenever there are accelerations (easy with real clocks)]



No acceleration.

Remember that B's turning around cannot physically change A's rate!

So, we have to conclude that, with real clocks, B's turning around cannot change either B's rate or A's rate…and therefore, neither rate is affected due to turning around!

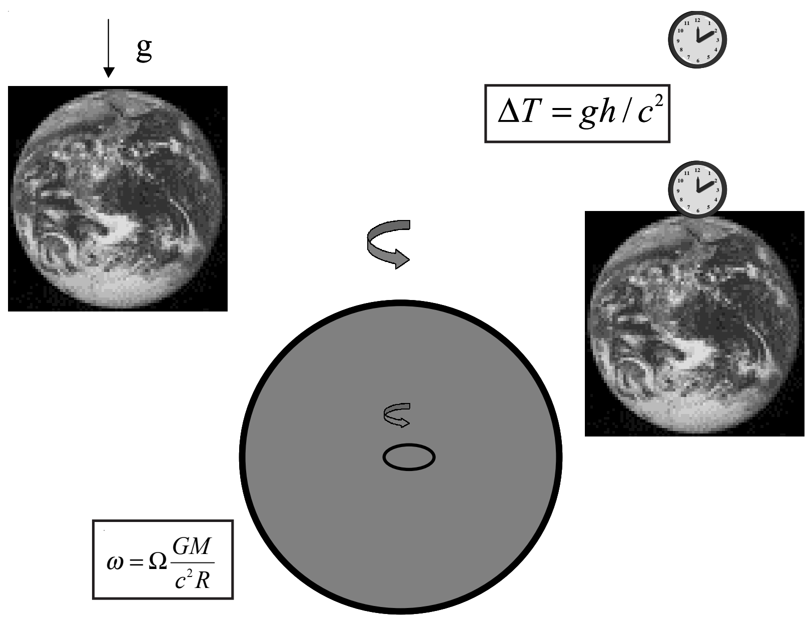
Einstein's 1918 resolution is incorrect – neither SR nor GR in empty space works here

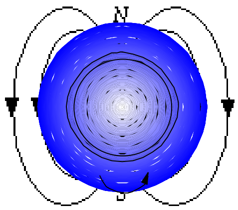
Therefore, there is some other physical reason for experimentally observed time dilation…

Is Special Relativity Correct?

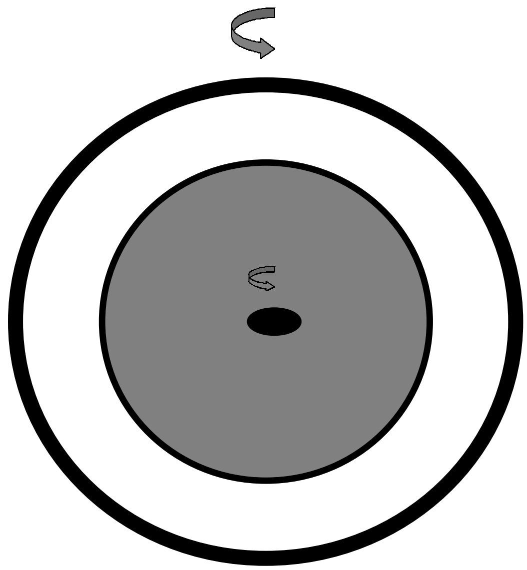
Can there be permanent physical changes like time dilation merely by moving relative to each other in empty space?

Some gravitational effects according to GR

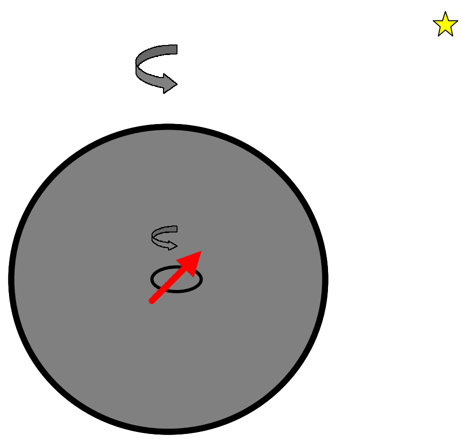




Gravitomagnetic field



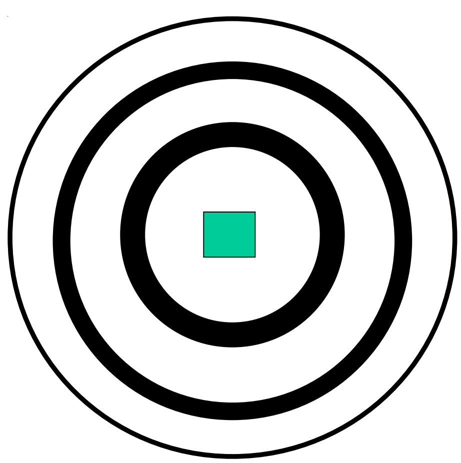
$$\omega = \Omega \frac{GM}{c^2 R}$$



$$\omega \simeq \Omega \frac{GM}{c^2 R}$$

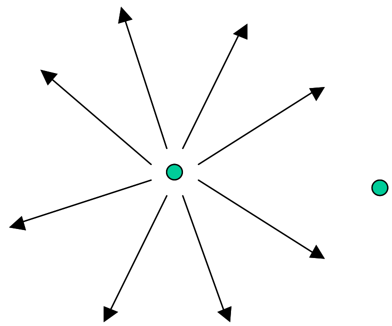
For earth, $\quad \dfrac{GM}{c^2 R} \simeq 10^{-9}, \;\; \Omega = 1/(24 \text{ hrs})$

Therefore, it will be inconsistent and indeed foolish to assume that moving within the massive Universe has no effect on local physics



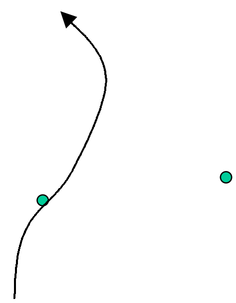
Electromagnetism

At rest



$$\phi(r-r') = -\frac{e}{|r-r'|}$$

In motion



$$\phi(r-r') = -\frac{e}{|r-r'|}\frac{1}{\sqrt{(1-v^2/c^2)}}$$

$$\vec{A} \simeq \frac{\vec{v}}{c}\phi$$

There is a four-vector potential

If there is a vector potential, then there are several new physical effects:

New forces:

- Time varying magnetic fields/ Vector potential

$$\vec{E} \sim -\frac{\partial \vec{A}}{\partial t} \sim -\phi\frac{\partial \vec{v}}{\partial t}$$

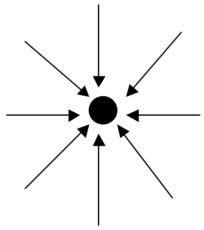
$$\vec{A} \sim \vec{v}\phi$$

If the velocity changes (either magnitude or direction), then there will be reactive electric forces that oppose the change

Also, if $\nabla \times \vec{A} \sim \nabla \times \vec{v} \neq 0$

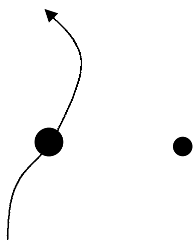
then there is a transverse force, $\vec{v} \times \nabla \times \vec{A} \equiv \vec{v} \times \vec{B}$

Relativistic Gravity



$$\phi(r-r') = -\frac{Gm}{|r-r'|}$$

Expectation for particles in motion:



$$\phi_g(r-r') = -\frac{Gm}{|r-r'|}\frac{1}{\sqrt{(1-v^2/c^2)}}$$

$$\vec{A}_g \simeq \frac{\vec{v}}{c}\phi_g$$

To second order in v/c, relativistic gravity is very similar to electromagnetism
"centrifugal forces are produced by rotation with respect to the mass of the earth and other celestial bodies, and not 'due to' motion relative to empty space".

What are the observable influences of the Universe?

Universe in rotating frame

$$\vec{A}_g \sim \vec{v}\phi_g$$

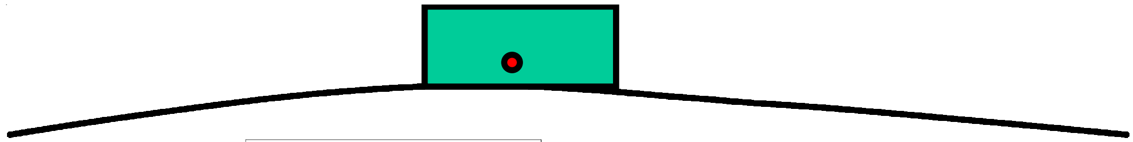
Currents of mass generates a vector potential

And its 'curl' is a gravitational magnetic field

- Acceleration à Changing vector potential à Inertial force
- Angular acceleration →Changing vector potential direction → Centrifugal force
- Uniform motion when curl (A_g) is not zero →Gravitational Lorentz force (v x B) → Coriolis force

Relativistic gravitational effects are very small near the earth and in the solar system.

Gravitational potential "here"



Earth: $\dfrac{GM_E}{c^2 R_E} < 10^{-9}$

Sun: $\dfrac{GM_S}{c^2 R_S} \simeq 10^{-8}$

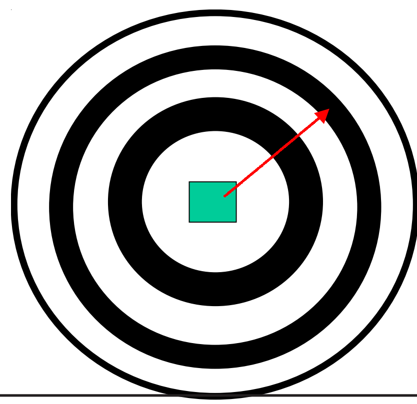
Galaxy: 10^{-6}

Distant masses dominate

What is the gravitational potential in this room due to all the galaxies that can be seen through the Hubble telescope ?

Farthest seen galaxy is at 13 billion light years

Average matter density of galaxies is 10^{-30} g/cm^3



$$\Phi_U \sim \int_{\text{Over all Galaxies}} G \cdot (4\pi\rho R^2 dR) / Rc^2$$

$$\sim 2\pi G\rho R^2_{\ H} / c^2 \approx 1$$

Earth: $\dfrac{GM_E}{c^2 R_E} < 10^{-9}$

Sun: $\dfrac{GM_S}{c^2 R_S} \simeq 10^{-8}$

Galaxy: 10^{-6}

All Galaxies upto 13 billion l.y: $\dfrac{\Phi_U}{c^2} \simeq \sum \dfrac{GM_i}{c^2 R_i} \simeq 10^{-1}$

The inferred value of average density (including 'unseen matter') is 10 times larger than the average density of luminous matter. Therefore, the local gravitational potential is indeed equal to c^2 !

An important fact in the matter filled universe:

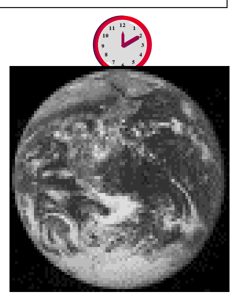
When there is matter, motion generates anisotropy (a direction for the flow/current of matter). This means that the metric HAS to change. Therefore, Lorentz transformation is not legitimate in the presence of the matter-filled universe, even if the spatial geometry is flat.

And the universe is once-given, with its gravitational field.

What are the gravitational effects on clocks and scales ?

$$\Phi'_U(V)/c^2 = \frac{\Phi_U/c^2}{\sqrt{(1-V^2/c^2)}}$$

$$\Delta T = gh/c^2 = \Delta\phi/c^2$$



So, a moving clock in the presence of the matter in the universe should slow down gravitationally, due to the different gravitational potential.

$$\frac{\Delta T}{T} = \frac{\Delta\Phi}{c^2} = \frac{1}{c^2}\left[\Phi(1+\frac{V^2}{2c^2})-\Phi\right] = \frac{1}{c^2}\left[\frac{\Phi V^2}{2c^2}\right] \simeq \frac{-V^2}{2c^2}$$

What are the gravitational effects on clocks and scales ?

At present we have two different reasons for the slowing down of a moving clock.

1) Special Relativity predicts

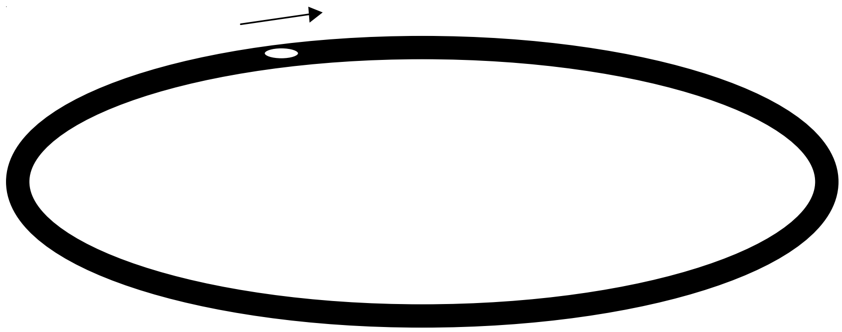
$$T' = T\sqrt{(1-v^2/c^2)} \approx T(1-v^2/2c^2)$$

$$\Delta T \simeq -v^2/2c^2$$

2) Gravitational effect of the masses in the Universe :

$$\frac{\Phi_U/c^2}{\sqrt{(1-V^2/c^2)}} \simeq \frac{1}{\sqrt{(1-V^2/c^2)}}$$

$$\rightarrow \Delta T \simeq -(V^2/2c^2)$$

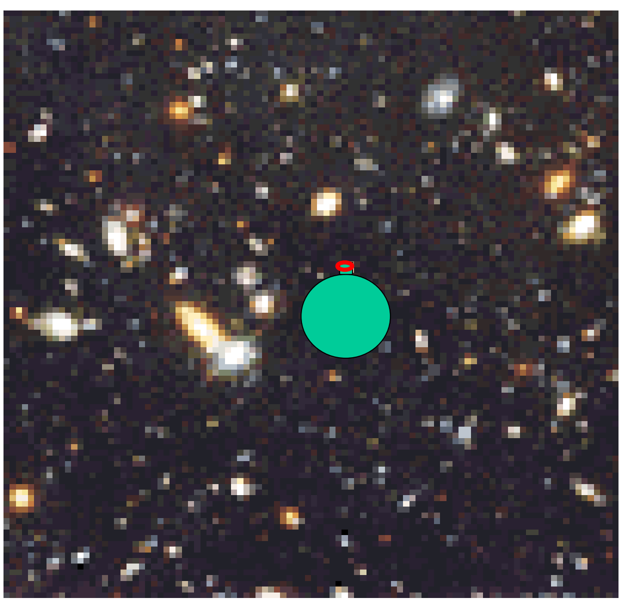


Muon rest lifetime $t_0 \simeq 2.197\,\mu s$

Storage ring (1978) v/c $\simeq 0.99942$

$$t_0 \sqrt{1 - v^2/c^2} \simeq 29.36 \times 2.197 = 64.5\,\mu s$$

Measured $\simeq 64.4\,\mu s$

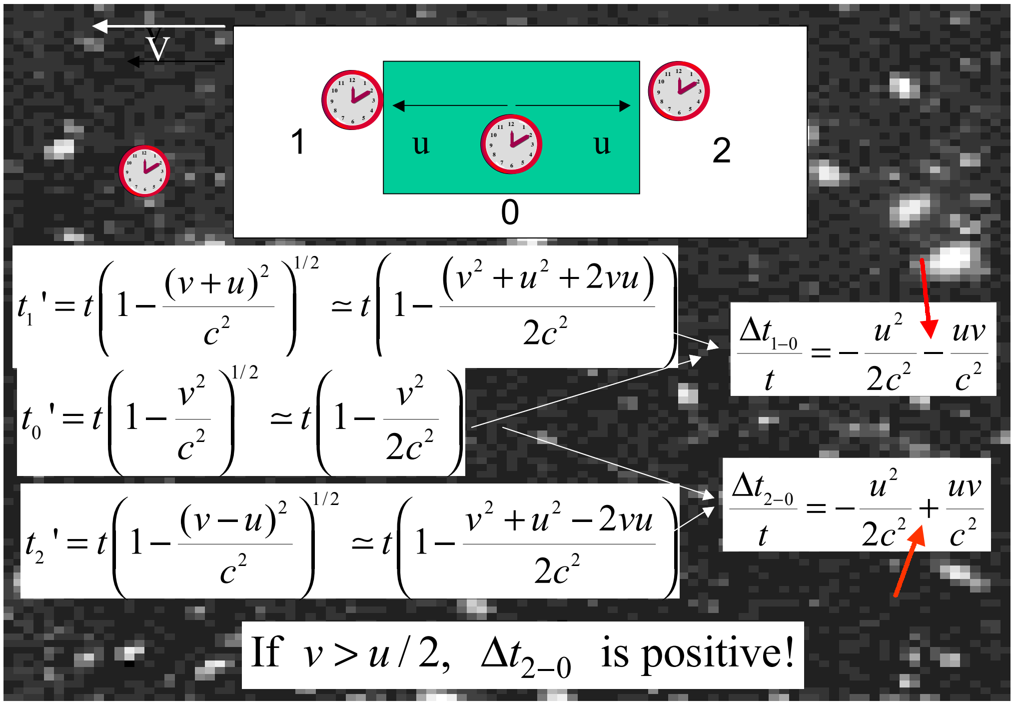


Gravitational effect + Special relativity effect = 128.8 micro-sec.

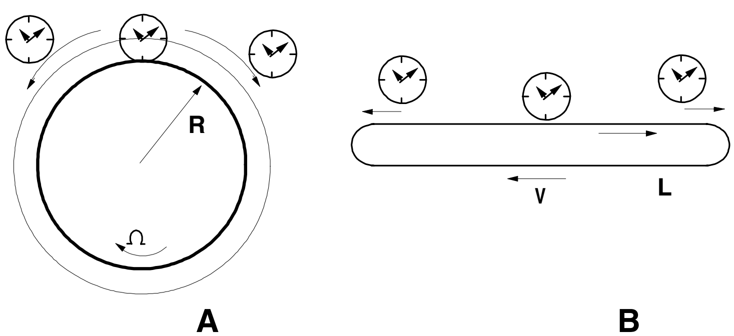
Measured = 64.4 micro-s !

One of these is ruled out experimentally !

Since galaxies and other matter exists, and if GR is correct, then SR is experimentally invalidated!



A transported clock can run faster than a stationary clock !!



$$\Delta T = \pm vuT/c^2 = \pm v\,d/c^2$$
$$= \pm\frac{1}{c}\oint_{round\ trip} A_g \cdot dx$$

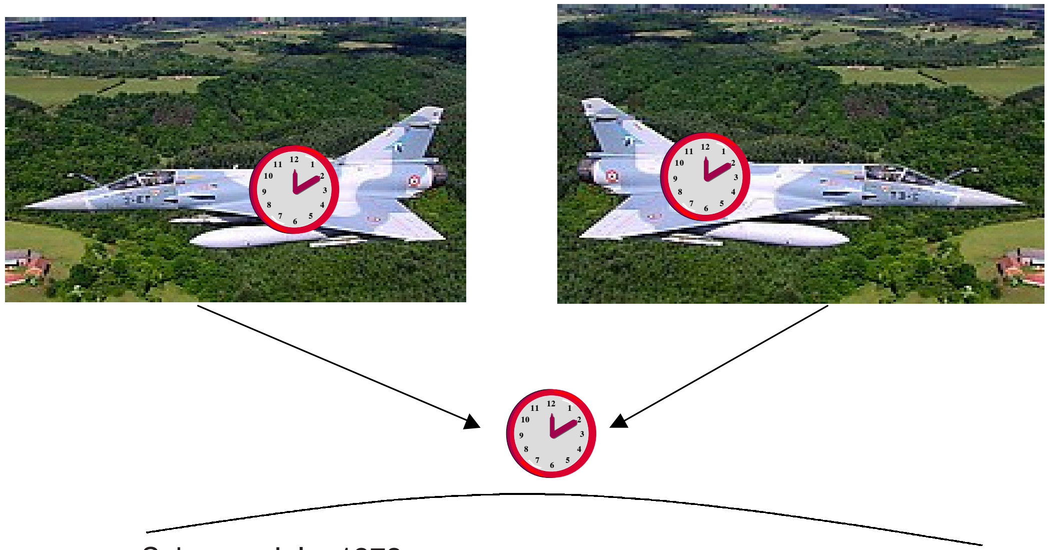
"If one of two synchronous clocks at A is moved in a closed curve with constant velocity until it returns to A, the journey lasting t seconds, then by the clock that has remained at rest the travelled clock on its arrival at A will be **½ tv^2/c^2** second slow"

A. Einstein, 1905

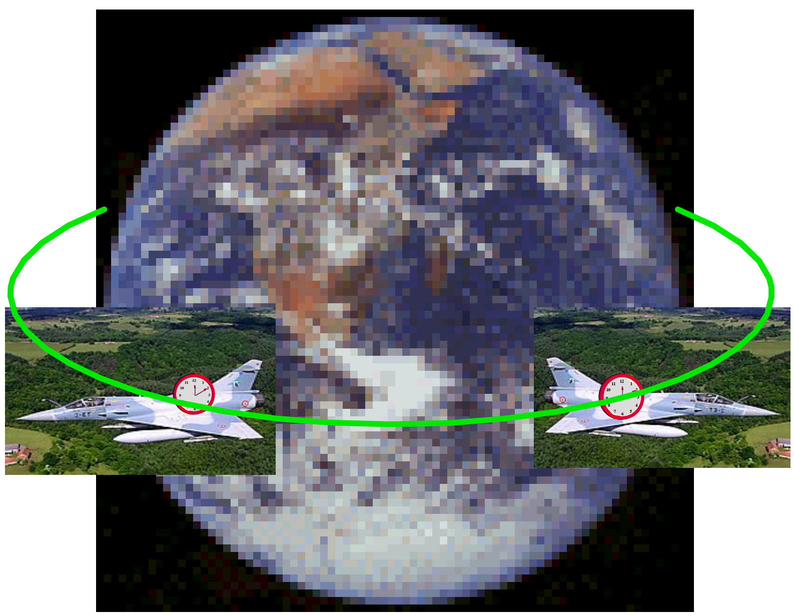
Is this prediction correct ?

Is a theory of relativity based on relative velocities (special relativity) in conflict with experiments ?

The Hafele-Keating experiment



Science, July, 1972



Measured values (relative to clock at rest):

$$\delta t_{Measured} \quad -59 \pm 10 \quad 273 \pm 7$$

After subtracting gravitational effect of earth,

$$\delta t_{Measured} \quad -204 \pm 20 \quad 94 \pm 20$$

East West

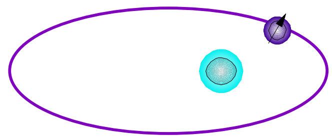
Disagrees with SR

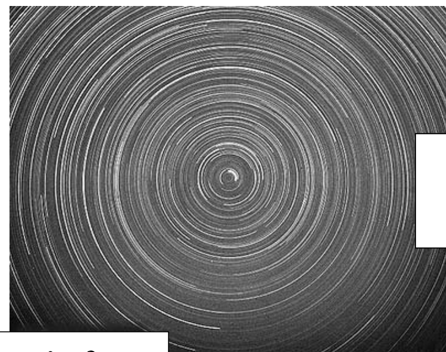
Westward clock DID run faster than the laboratory clock!

The correct resolution of the twin paradox :

The clock that moved more w.r.t the matter in the preferred frame of the universe runs slower. The effect is gravitational. There is no physical effect whatsoever due to 'moving relative to each other'

Generalization to quantum systems



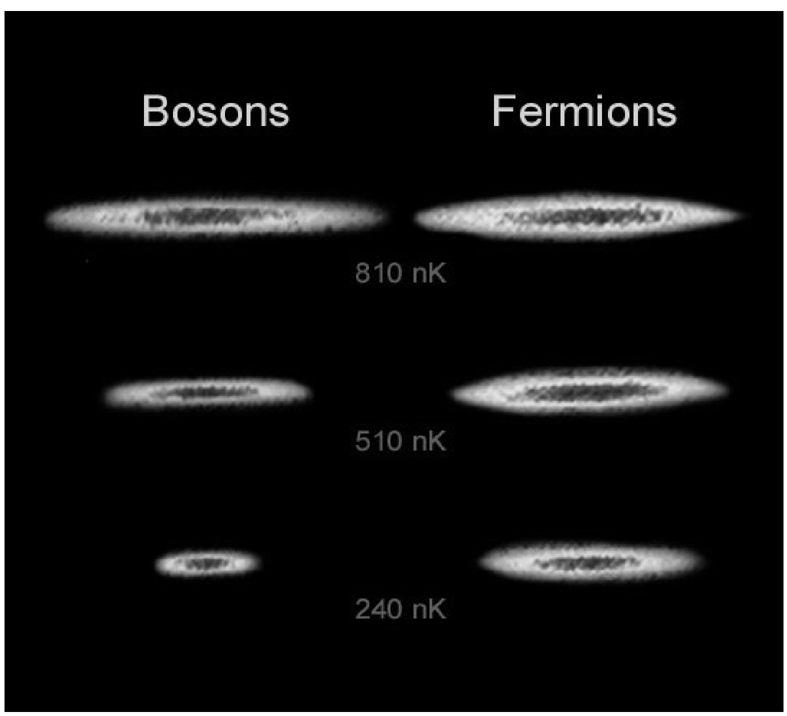


$$\vec{\nabla} \times A_g = B_g = \frac{\phi}{c^2}\Omega$$

Universe in electron's frame

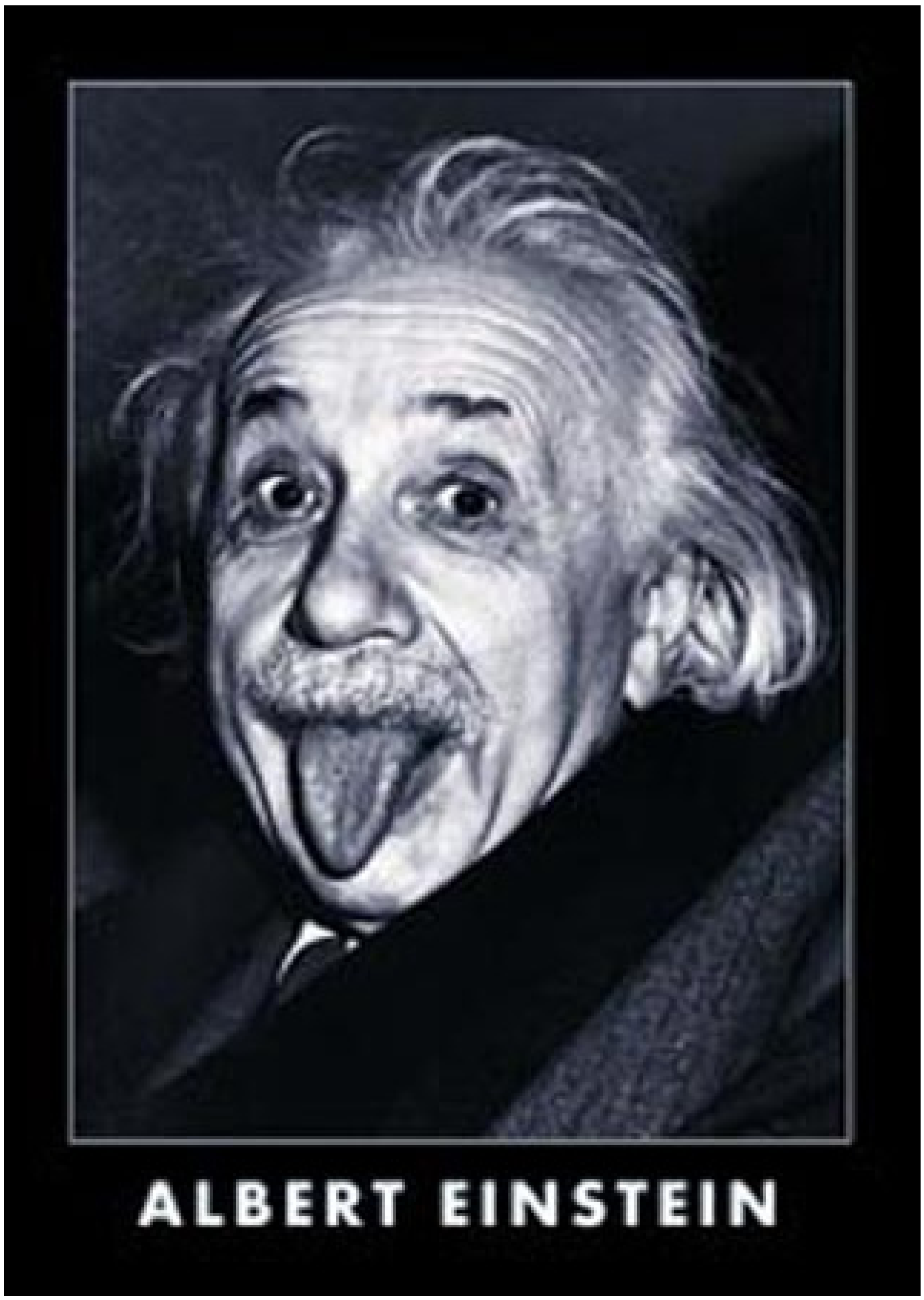
NOT A KINEMATICAL EFFECT !

The calculated quantized gravitational magnetic energy is half the magnetic fine structure splitting, with a negative sign !



Summary

- The massive Universe gravitationally affects classical and quantum dynamics in a significant way.
- Description of motion in terms of relative velocities is not consistent with presence of so much matter filling the universe – there is a preferred frame.
- Special relativity has to be replaced by Cosmic Relativity in the ‘once given’ Universe. After a good 100 years, it is definitely the end of special relativity.



Why was Einstein dissatisfied with Quantum Mechanics?

and …
Where does that lead us?

Prof. T. P. Singh
TIFR, Mumbai

The World According to Newton (17th-19th century)

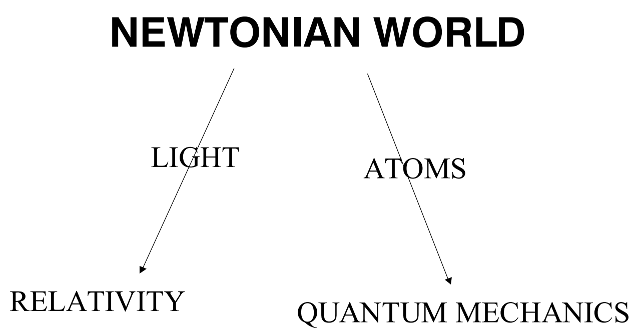
- Material bodies live in space and time.
- Motion is relative. Speeds are relative.
- The motion of bodies is deterministic – given the position and velocity of an object, its motion is uniquely determined.

The Newtonian picture of the Universe lasted for some two hundred years

But it had to be then modified, because it could not explain newly discovered

o properties of LIGHT

o properties of ATOMS



Relativity tells us that

NOTHING MOVES FASTER THAN

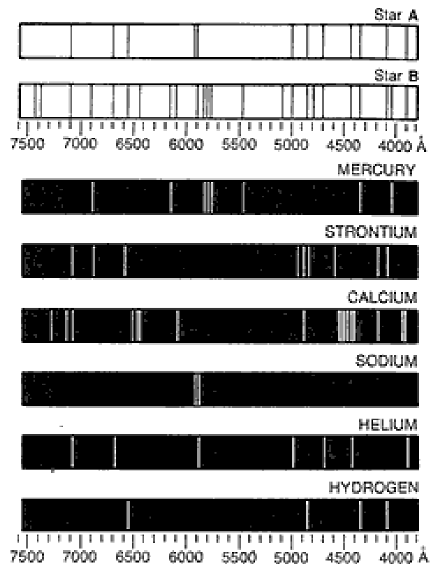
LIGHT

and …

THE WORLD IS CAUSAL

- IF AN OBSERVER FINDS THAT EVENT ‘A’ HAPPENS BEFORE EVENT ‘B’
- THEN …
- ALL OTHER OBSERVERS ALSO AGREE THAT EVENT ‘A’ HAPPENS BEFORE EVENT ‘B’

HOW ATOMS CHANGED OUR NEWTONIAN PICTUR OF THE WORLD



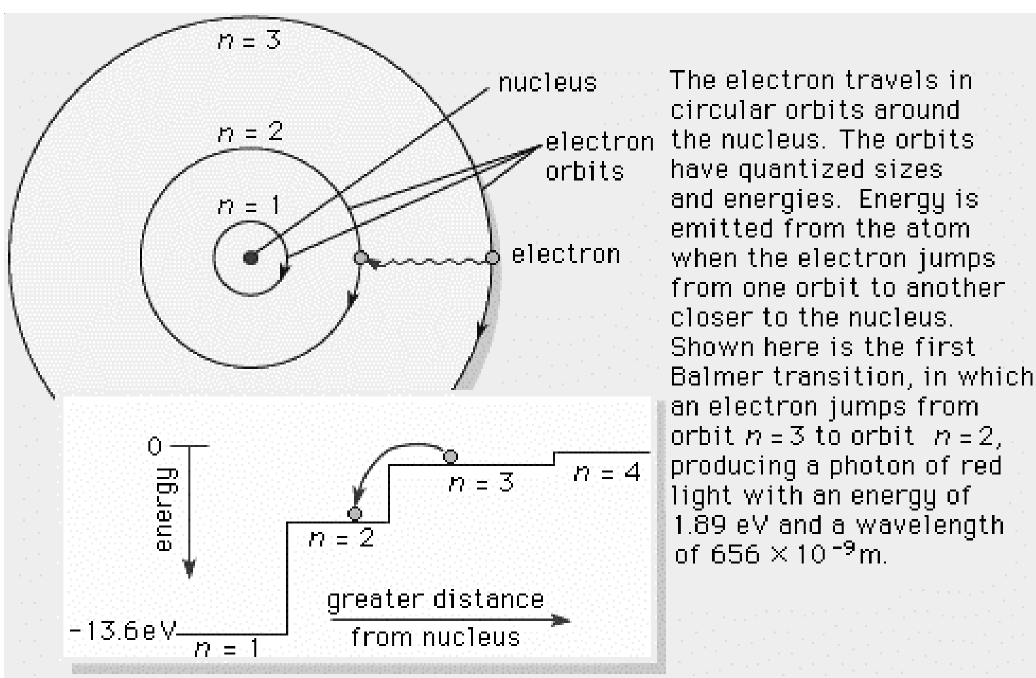
NEWTON CANNOT EXPLAIN ATOMS

• If Newton's mechanics is applied to the hydrogen atom, it predicts that the electron will fall into the nucleus! No spectrum.

• Enter Bohr (1913): Proposed that

(i) The electron has a state of lowest energy.

(ii) Its angular momentum is quantized in units of Planck's constant.



A NEW MECHANICS

- The work of Neils Bohr, followed by the ideas of de Broglie and Einstein on wave-particle duality …
- LED TO THE BIRTH OF QUANTUM MECHANICS (1926).

THE QUANTUM LAWS OF MOTION

- The position and momentum of a particle cannot be simultaneously measured accurately. q p – p q = i h••

THE END OF NEWTONIAN DETERMINISM

EINSTEIN WAS DISSATISFIED WITH QUANTUM MECHANICS !

- Correct and logically consistent, but incomplete.
- (Einstein nominated Heisenberg and Schrodinger for the Nobel Prize).

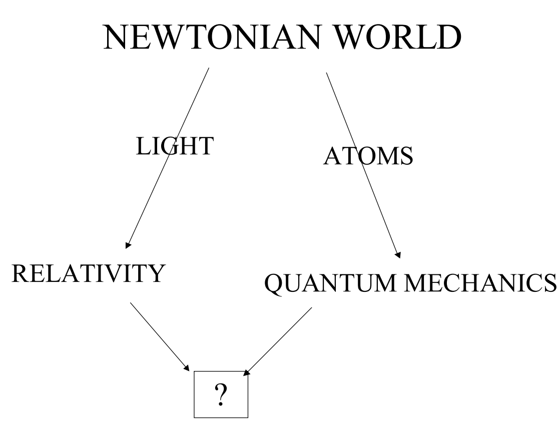
THE EPR ARGUMENT

- Suppose two particles with respective momentum (q_1, p_1) and (q_2, p_2) are in a state with definite momentum $P = p_1 + p_2$ and definite position $q = q_1 - q_2$.
- The two particles are allowed to interact and measurements are made on particle 1 long after the interaction, without disturbing particle 2.
- Measure p_1 and one instantaneously knows p_2. Measure q_1 and one instantaneously knows q_2.
- Since there can be no acausal influence, quantum mechanics is incomplete.

Einstein versus Quantum Mechanics

- Quantum Mechanics: There is indeterminism. There is also an acausal influence, which does not violate any experimental results.
- Einstein: There can be no acausal influence. Hence there can be no indeterminism. Quantum Mechanics is incomplete.

QUANTUM INDETERMINISM IS IN CONFLICT WITH CAUSALITY



Einstein's Vision

- To understand quantum phenomena as a consequence of an 'overdetermined' system of differential equations.
- Unfortunately, unrealized …

and …
Where does that lead us?

Quantum Mechanics without Classical Spacetime

- As we saw, the classical picture of spacetime and causality is in conflict with quantum mechanics.
- Classical spacetime is, however, produced by classical bodies, according to Einstein's general relativity, and hence has no place in quantum mechanics.
- It is this usage of classical spacetime which makes quantum mechanics incomplete.

How could one remove this incompleteness?

An idea …

NONCOMMUTATIVE GEOMETRY

- Noncommutative geometry, developed by Alain Connes in the 1980s, is a natural generalization of the geometry of Riemann.
- In a noncommutative geometry, coordinates of spacetime do not commute with each other : x * y does not equal y * x

Proposal …

- Quantum mechanics should first be described using noncommuting coordinate systems. There is an invariance under coordinate transformations.
- Such a description possibly allows for acausal influences.
- In the presence of classical bodies, classical spacetime becomes available, and the above description should reduce to standard quantum mechanics.

How could one test this idea? …

Towards experiment …

- In physics, there is a fundamental mass scale, called the Planck mass, and defined as:

$$m_{Planck} = \sqrt{\bullet c/G} \approx 10^{-5} \text{grams}$$

- Quantum mechanics has been applied and experimentally tested only for particles with mass much smaller than Planck mass.

Towards experiment …

- The description of quantum mechanics using noncommutative geometry predicts that just below the Planck mass scale, the theory actually becomes nonlinear.
- These non-linearities should be looked for, experimentally.
- Does the non-linearity open up a way for addressing indeterminism?

There is no doubt that quantum mechanics has seized hold of a beautiful element of truth and that it will be a touchstone for a future theoretical basis in that it must be deducible as a limiting case from that basis, just as electrostatics is deducible from the Maxwell equations of the electromagnetic field or as thermodynamics is deducible from statistical mechanics.

EINSTEIN (1936)

Einstein and Light Quanta

Prof. Arvind Kumar
Director, Homi Bhabha Science Education Centre

I Preludes to Einstein's Work

II Einstein's route to the light quantum hypothesis

III Photoelectric effect and Compton effect

IV Light quanta : Skepticism, struggles and triumphs

☞ Einstein's 1916 derivation of Planck's law

☞ Bose's derivation of Planck's law : Photon statistics (1924)

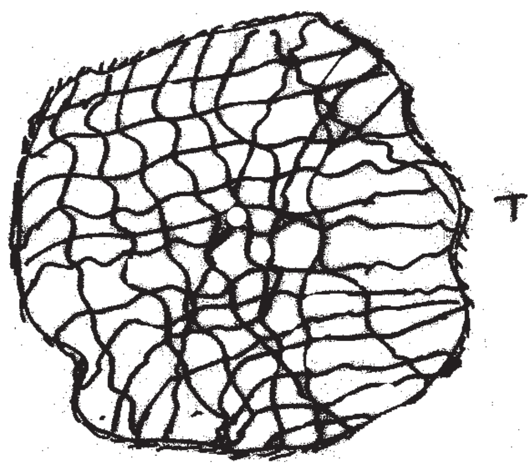
☞ Dirac's quantization of electromagnetic field (1927)

☞ Wave-Particle duality

I. Preludes to Einstein's Work

1. 1859 : Gustav Kirchhoff

Black body radiation or thermal radiation in a cavity with walls maintained at a certain temperature, in equilibrium :



Energy per unit volume per unit frequency interval is a universal function of frequency and temperature i.e. it is independent of the size, shape or material of the cavity/body.

Energy density between υ to $\upsilon + \Delta\upsilon = \rho(\upsilon, T)\ \upsilon\nabla$

Challenge

To obtain the form of the universal function (Kirchhoff's function) $\rho(\upsilon, T)$ that was true for all υ.

To derive a theoretical justification for the form of $\rho(\upsilon, T)$ so obtained.

2. Progress before Planck's law

Stefan - Boltzmann Law (1883, 84)

Total energy density of thermal radiation (i.e. summed over all frequencies) is proportional to the fourth power of absolute temp.

$$U(T) = \int_0^\infty \rho(\upsilon, T)\, d\upsilon \;\alpha\; T^4$$

Boltzmann gave a thermodynamic proof of this law in 1884.

Earlier (1883), Stefan arrived at this law experimentally.

Wien's Scalling law (1893)

Wien used thermodynamic reasoning to show that

$$\rho(\upsilon, T) = \upsilon^3 f\left(\frac{\upsilon}{T}\right)$$

where f is a universal function of only one argument : υ / T

Wien's law for black body radiation (1896)

$$\rho(\upsilon / T) = \alpha\, \upsilon^3\, \overline{e}^{\beta\upsilon / T}$$

Conjecture suggested by Maxwell's velocity distribution in a classical ideal gas.

Rayleigh - Jeans Law (1900, 1905)

Equipartition theorem of classical statistical mechanics applied to thermal radiation as a system :

$$\rho(\upsilon / T) = \frac{8\pi^2}{c^3} kT$$

C : speed of light
K : Boltzmann constant

Experiments by Paschen (1897); Rubens and Kurlbaum (1900) showed that

Wien's law : Valid in high frequency limit

R - J law : Valid in low frequency limit

3. Enter Planck

Planck obtained an interpolation between the two limiting forms of black body radiation law : (October 19, 1900)

$$\rho(\upsilon / T) = \frac{8\pi\upsilon^2}{c^3} \frac{h\upsilon}{e^{h\upsilon / kT} - 1}$$

h : a new fundamental constant of nature with the dimension of action now called Planck's constant.

For $\frac{h\upsilon}{kT} >> 1 \quad \rho(\upsilon, T) \rightarrow \frac{8\pi h}{c^3} \upsilon^3 \, \overline{e}^{h\upsilon/kT}$ Wien's law

For $\frac{h\upsilon}{kT} >> 1 \quad \rho(\upsilon, T) \rightarrow \frac{8\pi kT}{c^3} \upsilon^2$ R - J law

Planck's theoretical derivation of the blackbody radiation law : Birth of Quantum Theory (December 14, 1900)

i) **Equation for joint equilibrium of matter and radiation**

$$\rho(\upsilon, T) \rightarrow \frac{8\pi\upsilon^2}{c^3} U(\upsilon, T) \qquad \text{Plank's link}$$

where $U(\upsilon, T)$ is the average energy of a charged material oscillator.

ii) **Using Planck's law for $\rho(\upsilon, T)$, determine $U(\upsilon, T)$:**

$$U(\upsilon, T) = (e^{h\upsilon/kT} - 1)$$

Failure of classical equipartition theorem is evident at high frequency (For low frequency, $U(\upsilon, T) = kT$)

using

$$T\,dS = dU$$

(where T is a function of U for fixed υ) and integrating

$$S = K\left[\left(1 + \frac{U}{h\upsilon}\right) \ln\left(1 + \frac{U}{h\upsilon}\right) - \frac{U}{h\upsilon} \ln \frac{U}{h\upsilon}\right]$$

iii **Derivation of S :**

N linear oscillators

$U_N = NU \qquad S_N = NS$

$S_N = K \ln W_N$

$U_N = P\varepsilon$ (Quantum postulate : Total energy is made of finite energy elements ε)

$$\frac{P}{N} = \frac{U}{\varepsilon}$$

W_N = Number of ways in which P indistinguishable energy elements can be distributed over N distinguishable oscillators.

N = 2

P =3

$$W_N = \frac{(N-1+P)!}{P!(N-1)!}$$

$(3\varepsilon, 0);(0, 3\varepsilon)$

$(2\varepsilon, \varepsilon);(\varepsilon, 2\varepsilon)$

Using this in $S_N = k \ \ln W_N$ and applying stirling approximation;

$$S = K\left[\left(1+\frac{U}{\varepsilon}\right)1n\left(1+\frac{U}{\varepsilon}\right)-\frac{U}{\varepsilon}1n\frac{U}{\varepsilon}\right]$$

which is the earlier expression for S (step (ii))

With $\varepsilon = h\upsilon$

II. Einstein's Route to the Light Quantum Hypothesis (March 1905)

Fine example of heuristic approach

- Planck's classical link for joint equilibrium of matter and radiation :

$$\rho(\upsilon, T) = \frac{8\pi\upsilon^2}{c^3} \quad U(\upsilon, T) \qquad \text{(A)}$$

By classical equipartition theorem for the material oscillator

$$U(\upsilon, T) = kT$$

$$\rho(\upsilon, T) = \frac{8\pi\upsilon^2}{c^3}kT \qquad \text{R - J law}$$

Disagrees with experiment (at high υ) and also has the disastrous consequence that the integral over diverges i.e. Stefan - Boltzmann constant is infinite !

Einstein realised that R - J law is based on the solid foundations of classical mechanics and statistical mechanics and its failure signified there was something basically wrong with both.

- Planck's law is experimentally valid but has no proper theoretical basis.
- Wien's law is empirically valid at high⊙, where the classical R-J law fails. So Wien's law is likely to contain some non-classical features. Use Wien's law and examine the thermodynamics of radiation without using Planck's link (A). Do not use Planck's law for a start - this was Einstein's master stroke.
- Einstein arrived at the light quantum hypothesis by studying the volume dependence of entropy of Wien radiation. He found an analogy between this and the corresponding dependence of entropy of a classical ideal gas of material particles. The analogy led him to the

Light quantum hypothesis

"Monochromatic radiation of low density (i.e. within the domain of validity of the Wien radiation formula) behaves in thermodynamic aspect as if it consists of mutually independent energy quanta of magnitude hυ".

Einstein's derivation

$\phi(\upsilon, \mathrm{T})$ = entropy density per unit volume per unit frequency interval.

Use the Thermodynamic relation;

$$\mathrm{T}^{-1} = \frac{\partial \phi}{\partial \rho}$$

Use $\rho = \alpha \upsilon^3 \mathrm{e} - \beta \upsilon / \mathrm{T}$ Wien's law

$$\phi = \frac{\rho}{\beta \upsilon} \left(\ln \frac{\rho}{\alpha \upsilon^3} - 1 \right)$$

$\mathrm{S}(\upsilon, \mathrm{V}, \mathrm{T})^{-} = \phi \mathrm{V} \mathrm{d} \upsilon$ entrophy between υ to $\upsilon +$ dυ

$\mathrm{E}(\upsilon, \mathrm{V}, \mathrm{T}) = \rho \mathrm{V} \mathrm{d} \upsilon$ entrophy between υ to $\upsilon +$ dυ

$$\mathrm{S}(\upsilon, \mathrm{V}, E) - \mathrm{S}(\upsilon, \mathrm{Vo}, \mathrm{E}) = \frac{\mathrm{E}}{\beta \upsilon} \ 1\mathrm{n} \left(\frac{\mathrm{V}}{\mathrm{Vo}} \right) = \mathrm{k} 1\mathrm{n} \left(\frac{\mathrm{V}}{\mathrm{Vo}} \right)^{E / h\upsilon}$$

Compare this with the standard formula for a classial ideal gas of n material particles:

$$\mathrm{S}(\mathrm{V}, \mathrm{E}) - \mathrm{S}(\mathrm{Vo}, \mathrm{E}) = \mathrm{k} \ 1\mathrm{n} \left(\frac{\mathrm{V}}{\mathrm{Vo}} \right)^{\mathrm{n}}$$

$\rightarrow$ Light quantum hypothesis

We now know that the derivation is not rigorous on several grounds :

- Boltzmann statistics not true for photon gas. Photons obey Bose statistics.
- Photon number is not conserved.

But luckily in the Wien regime

Boltzmann counting and Bose counting give the same answer.

Photon non-conservation does not play any effective role.

This is why Einstein got away with the non-rigorous derivation and made the great discovery.

So far a formal result - an analogy.

Next, the big jump :

The Heuristic Principle

"If, in regard to the volume dependence of the entropy, monochromatic radiation (of sufficiently low density) behaves as a discrete medium of energy quanta of magnitude $h\nu$, then this suggests an inquiry as to whether the laws of generation and conversion of light are also constituted as if light were to consist of energy quanta of this kind".

Heuristic Principle applied to three experimental observations :

Stokes' rule in photoluminscence

Photoelectric effect

Ionization of gases by ultraviolet light.

The highlight of the application was the photoelectric effect

- cited in Nobel Prize for him in 1922 :

"...... for his services to theoretical physics and in particular for his discovery of the law of the photoelectric effect".

III. Photoelectric and Compton effects

Photoelectric effect

1887 Discovered by Hertz

1902 Experiments by Lenard ejected electron's maximum energy independent of intensity; increasing with frequency. Threshold frequency

1905 photon of energy $h\upsilon$ transfers all its energy to a single electron. (Einstein's picture)

$E_{max} = h\upsilon - W$

W = Workfunction of the metal

Verified by an extensive series of experiments by Milikan (up to 1915).

Completing the light quantum picture : directed momentum (photon)

Photon carries an energy parcel of $h\upsilon$ and also has a directed momentum $h\upsilon/c$

1909 : momentum fluctuations of a mirror immersed in thermal radiation as a result of fluctuations in radiation pressure.

1916 : Energy and momentum balances in a molecular transition (emission and absorption) keeping Planck's distribution for radiation and Boltzmann's distribution for molecules stable.

Compton effect (Arthur Compton 1923)

Scattering of a photon by a (nearly) free electron.

Applying energy and momentum conservation to photon-electron collision.

$$\Delta\lambda = \frac{h}{mc}(1-\cos\theta)$$

Where $\Delta\lambda$ is the change in wave length of the photon and θ is the photon scattering angle.

Relation verified experimentally giving a strong support to the photon picture.

IV Light quanta : Skepticism, struggles and triumphs

- ''I insist on the provisional character of the concept (light quanta) which does not seem reconcilable with the experimentally verified consequences of the wave theory'' (Einstein, 1911)
- ''Einstein's photoelectric equation ...... appears in every case to predict exactly the observed results...... Yet the semi corpuscular theory by which Einstein arrived at this equation seems at present wholly untenable''. (Millikan, 1915).
- ''I am not seeking the meaning of the quantum of action (light quanta) in the vacuum but rather in places where absorption and emission occur, and (I) assume that what happens in the vacuum is rigorously described by Maxwell's equations.'' (Planck, 1907)
- ''In sum, one can say that there is hardly one among the great problems in which modern physics is so rich to which Einstein has not made a remarkable contribution. That he may sometimes have missed the target in his speculations, as, for example, in his hypothesis of light quanta, cannot really be held too much against him, for it is not possible to introduce really new ideas even in the most exact sciences without sometimes taking a risk.''

(Planck proposing Einstein for election to the Prussian Academy of Sciences).

- ''I do not doubt any more the reality of radiation quanta, although I still stand quite alone in this conviction''. (Einstein, 1919)
- ''The experimental support of the theory indicates very convincingly that a radiation quantum carries with it directed momentum as well as energy'' (Compton 1923)''

Yet Bohr continued to remain a skeptic. He thought quantisation should refer to matter not radiation.

Bohr-Kramers-Slater (BKS) Proposal

Non - conservation of energy

Non - causality

Disproved experimentally

- Einstein's Work on Specific Heats

Take Planck's link based on classical physics to be true in the quantum domain. Abandon equipartition theorem and use the link to get modified expression for energy of a material oscillator.

Einstein's alternative derivation of Planck's Law (1916)

System : a gas of molecules interacting with radiation in thermal equilibrium

$$Nm = Pm \quad \exp\left(-\frac{E_m}{kT}\right)$$

$$dW_{mn} = N_m\left(\rho B_{mn} + A_{mn}\right) \; dt \qquad -m$$

$$dW_{nm} = N_n \; \rho B_{nm} \; dt \qquad -n$$

$$B_{nm} =: \text{absorption n} \rightarrow \text{m}$$

A_{mn} : spontaneous emission m $\rightarrow$ n

B_{mn} : induced emission m $\rightarrow$ n

In equilibrium,

$$dW_{mn} = dW_{nm}$$

Also

$$B_{mn} P_n = B_{nm} P_m$$

$$\rho = \alpha_{mn} \left\{\exp\left[\left(E_m - E_n\right) / kT\right] - 1\right\}^{-1}$$

$$\alpha_{mn} = \frac{A_{mn}}{B_{mn}}$$

$$\alpha_{mn} \alpha \upsilon^3 \qquad E_m - E_n = h\upsilon$$

Planck's law emerges. Bridge between Planck's law and Bohr's theory.

Chance in spontaneous emission : breakdown of classical causality

Bose's derivation of Planck's law : Photon statistics

Integrate one particle phase space d^3 x d^3 p over V and over all momentam between p^s and p^s + dp^s

$$V \times 4\pi (p^s)^2 \, dp^s$$

Multiply 2 to count two states of polarization.

$$8\pi V(p^s)^2 \, dp^s$$

use $p^s = h\upsilon^s / c,$ to get

h^3 Z^s

Since each cell has volume h^3

no. of cells Z^s between υ^s and $\upsilon^s + d\upsilon^s$:

$$\frac{8\pi V}{c^3}\left(\upsilon^s\right)^2 d\upsilon^s$$

which is the same as computed by counting the number of standing waves in a cavity with volume V.

Partition Z^s into number P_r^s, where P_r^s is the number of cells which contain r quanta with frequency υ^s. Let there be N^s photons in all with this frequency and let E be the total energy.

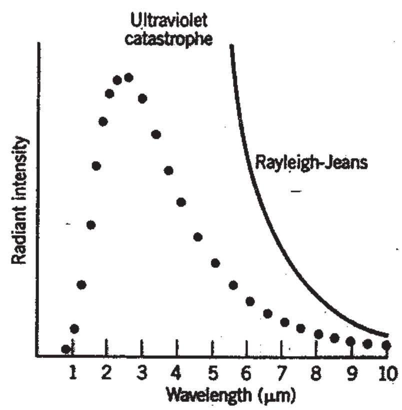


Fig. : The failure of the classical Rayleigh-Jeans formula to fit the onserved spectrum of radiant intensity. At long wavelengths of the theory approaches the data, but at short wavelengths the classical formula fails miserably.

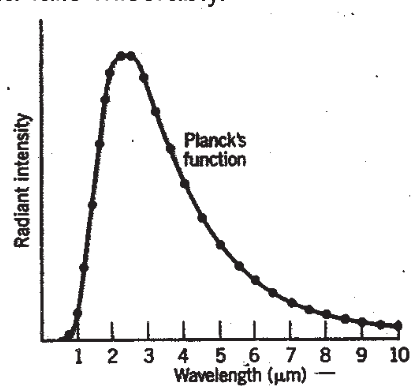


Fig. : Planck's function fits the observed data perfectly.

Then

$$Z^S = \sum_r P_r^S \qquad N^S = \sum_r r\, P_r^S$$

$$E = \sum_s N^S h\, \upsilon^S \qquad N = \sum_s N^S$$

Bose's counting procedure:

$$W = \prod \frac{Z^S!}{p_o^S!\, p_1^S! \ldots\ldots}$$

Maximum W as a function of p_r^S, holding Z^s and E fixed :

$$\sum_{s,r} \delta P_r^s \left(1 + 1n\, P_r^s + \lambda^s + \frac{1}{\beta} rh\, \upsilon^s \right) = 0$$

which leads to Planck's law. Note Z^s fixed means N is not fixed.

Actually, we now know

Z^s fixed constraint not needed.

E fixed constraint alone leads to Planck's law.

Three new features implicit in Bose's derivation :

1. Photon number not conserved
2. P_r^S are defined by how many particles are in a cell. Boltzmann's axiom of distinguishability disappears. Statistics of indistinguishable particles.
3. Statistical independence of cells. No statistical independence of particles.

♦———♦———♦———♦

Four great papers before modern quantum mechanics were due to

Planck

Einstein

Bohr

Bose

Einstein applied Bose's counting formula, made appropriate modifications necessary for an ideal gas of molecules, and obtained quantum statistics of an ideal gas, with the important consequence of B-E condensation.

Dirac completed the understanding in 1926

Boltzmann's fine-grained counting formula

$$N = \sum_i n_i \qquad E = \sum \varepsilon_i n_i$$

Number of microstates W

$$W = \frac{N_i}{\prod n_i!} \qquad \text{(Boltzmann statistics)}$$

$$= 1 \qquad \text{(Bose - Einstein statistics)}$$

Why did Einstein's 1905 derviation work ?

B - E statistics :

$$< n_i > \; = \; \left[\exp\left(h\upsilon / kT\right) - 1\right]^{-1}$$

$$<<1 \qquad \text{for} \;\; h\upsilon / kT >> 1$$

Apart from an irrelevant factor N!,
Boltzmann = B-E $\quad$ for $h\upsilon / kT >> 1$

Dirac's quantization of em field

- Field as a set of oscillators in memontum space.
- Quantisation of the oscillator as per canonical procedure of quantum theory
- Photon interpreted as a quantum of electromagnetic field.

Wave - Particle duality

1909 Einstein considered the full Planck's law - not just the Wien law - and used his energy fluctuation formula.

$$(\Delta E)^2 = \; < E^2 > \; - \; < E >^2$$

$$= \kappa T^2 \frac{\partial}{\partial T} < E >$$

For unit volume and radiation between υ and $\upsilon + \Delta\upsilon$

$$< E > \; = \; \frac{8\pi\upsilon^2}{c^3} \Delta\upsilon \frac{h\upsilon}{e^{h\upsilon / kT} - 1}$$

$$(\Delta E)^2 \; = \; \frac{c^3}{8\pi\upsilon^2 \Delta\upsilon} < E >^2 + h\upsilon < E >$$

$$\qquad\qquad\downarrow \qquad\qquad\qquad \downarrow$$

$$\qquad\qquad(\text{R-J}) \qquad\qquad (\text{Wien})$$

Fusion of wave-particle aspects of photon

1923 Wave-particle duality for electrons (Louis de-Brogile)

Quantum theory incorporates wave-particle duality but its deep understanding is so far elusive.

''All the fifty years of conscious brooding have brought me no closer to the answer to the question, 'what are light quanta?'.

Of course today every rescal thinks he knows the answer, but he is deluding himself'

(Einstein, a few years before his death)

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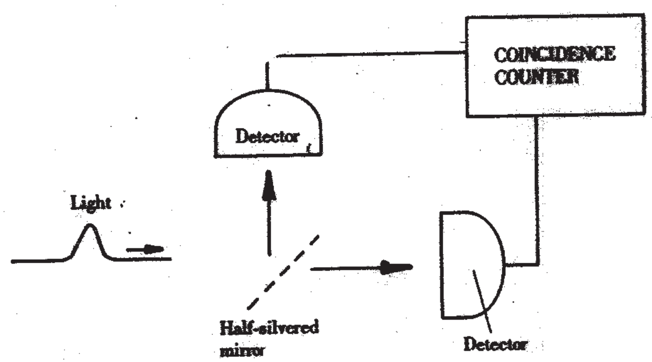
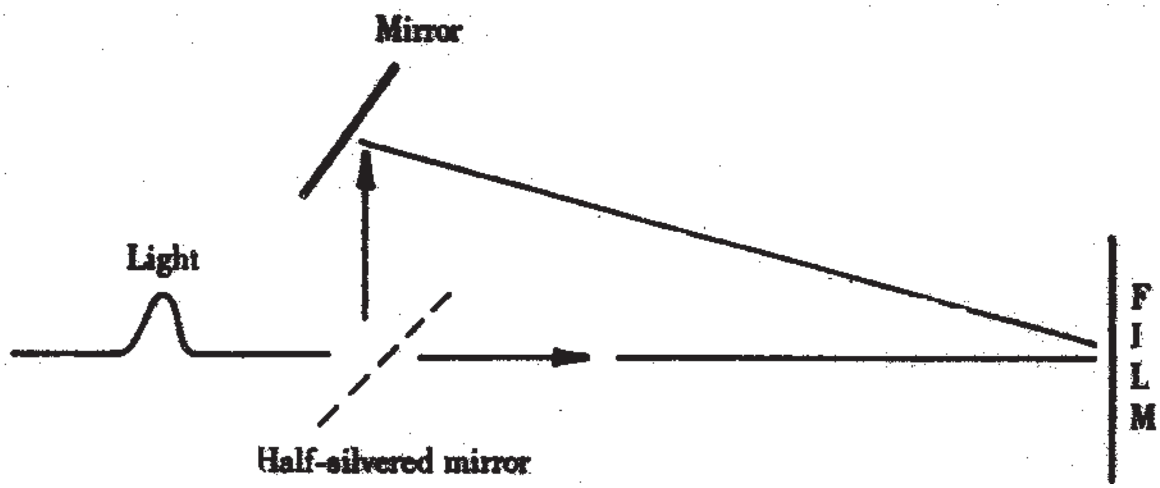


Light as a particle. In this experiment a single photon falling on the half-silvered mirror goes to one detector or the other, never both.



Light as a wave. Interference requires that light travel both paths to the film.

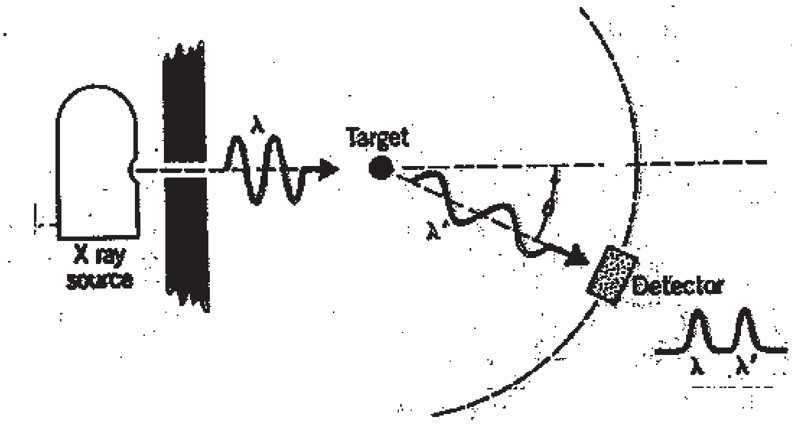


Fig. : Schematic diagram of Compton scattering apparatus. The wavelength λ'of the scattered X rays is measured by the detector, which can be moved to different positionsθ. The wavelength difference λ' - λ varies with θ.

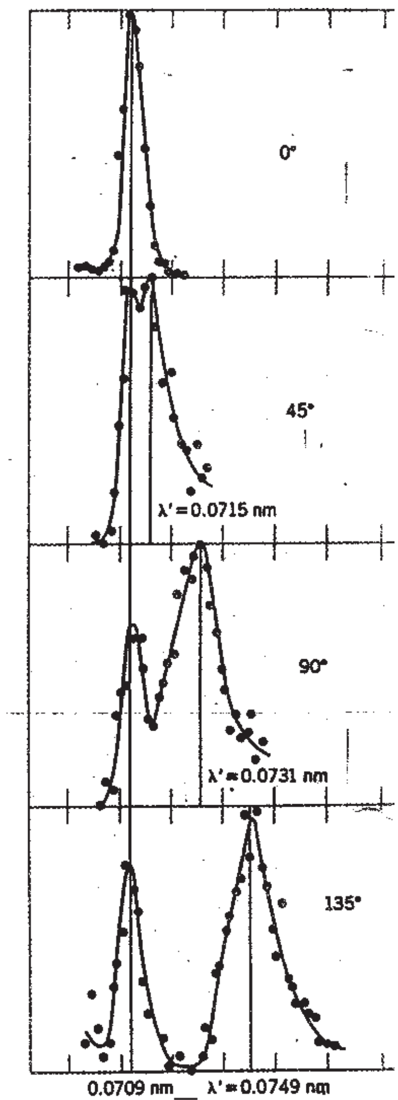


Fig. : Compton's original results for X-ray scattering.

A brief history of the Photoelectric Effect, 1905-2005

G. Ravindra Kumar
TIFR, Mumbai

The explanation of the photoelectric effect, for which Einstein won the Nobel Prize, forms the content of one of the papers that he published in 1905, revolutionizing physics in many ways. It may not have attracted compelling attention in the manner of its other, more ‘‘popular’’ companions like the theory of relativity, but as I attempt to show in this talk, it has had a remarkable effect in science and technology, improving our lives in so many ways. And the best part of it all is the fact that the photoelectric effect has acquired different meanings since 1905 and added new shades and dimensions. It may startle most people to realize that the two tenets that Einstein proposed in his interpretation are no more necessary or valid !

So what is the Photoelectric effect in 2005 ? Let us find out...........!

“Albert Einstein : some simple truths”

Ajit Kembhavi
IUCAA, Pune

Albert Einstein is known primarily for his theory of relativity, but he has made fundamental contributions to other areas of physics. Early in his career as a researcher, Einstein provided a very simple explanation of Brownian motion, which established experimentally the existence of atoms, he also provided a explanation of the photoelectric effect, assuming that light is made of particles. This led to the establishment of the quantum theory, a process that had been started by Max Planck. Einstein’s work is very simple and yet it involved revolutionary concept. These two works were done along with the discovery of special relativity in the golden year of 1905.

"Role of Relativity in Astronomy and Astrophysics"

Dr. S. M. Chitre

Emeritus Professor, Dept. of Physics, University of Mumbai

Abstract : The structure and evolution of stars had dominated the field of Astrophysics in the first half of the 20th century. Despite the pre-eminent position of Relativity during this period, it hardly had any interaction with Astrophysics, except for the fruitful confluence of special relativity and quantum physics which culminated in the prediction of the limiting mass for white Dwarfs by Chandrasekhar. This was largely because the relativistic effects associated with the gravitational bending of light, gravitational shift of spectral lines and the precession of the perihelion of planet Mercury's orbit were regarded to be too small to be of any relevance in the wider contextof astrophysics.

In the realm of extragalactic astronomy, however, general relativity continued to direct the course of observational studies once the expansion of the Universe was established by Hubble and it also opened up the tantalizing possibility of manufacuring the light elements in the first few minutes of cosmic expansion following the Big Bang.

The increasing role of strong gravitational fields in controlling the energetic phenomena in astrophisics was recognized soon after a succession of discoveries were reported in the second half of the 20th century such as violent events in the nuclei of galaxies, quasars, pulasars, cosmic microwave background radiation, X-ray and Gamma ray sources. This renaissance ushering in the golden age of astronomy was made possible largely because of the technological advances that enabled the observers to survey the Universe simultaneously through most of the windows from radio to gamma rays. It will be amusing to speculate if the advances made during this period will be matched by even more exciting developments in this millennium !

- Despite its phenomenal impact in the first quarter of the 20th century, Relativity had hardly any interaction with Astrophysics.
- Relativistic effects associated with gravitational bending of light, gravitational shift of spectral lines and precession of the perihelion of planet Mercury were considered too small to be relevant in broader context of Astrophysics.
- However, in the realm of extra-galactic astronomy General Relativity played a crucial role to account for the observed expansion of the Universe [Hubble & Humason]
- Physics of stars and galaxies that are the main building blocks of the Universe provides the basic fibre for the cosmic tapestry.
- General relativity played a central role in directing course of observational and physical cosmology: Expansion of the universe and Big-Bang Nucleosynthesis (Thermodynamics and Cosmology)
- An important ingredient introduced in cosmology was thermodynamic history and the possibility of manufacturing the light elements (H, He, D, Li) in the very early hot, dense phase of expanding universe [Gamow].

Astronomy has over the ages been a testing ground for theories of gravity.

- **Newton:** Sizes and shapes of planetary orbits
- **Einstein:** Binary (double) Pulsars as powerful transmitters of gravitational waves.

Astronomy has always been driven by technological advancements.

- **<u>Some landmarks:</u>**
- 1610 [Galileo]
- 1910 - 1930 [Harlow Shapley, Edwin Hubble]
- 1950 – 1960 [Martin Ryle, Bernard Lowell, B. Y. Mills]
- 1960 – 1970 [Rossi, Giacconi]
- 1988 - [COBE, HST, CHANDRA, SPITZER …]

GOLDEN AGE OF ASTRONOMY

ACTIVE GALACTIC NUCLEI [QUASARS] (1963)

COSMIC MICROWAVE BACKGROUND RADIATION (1965)

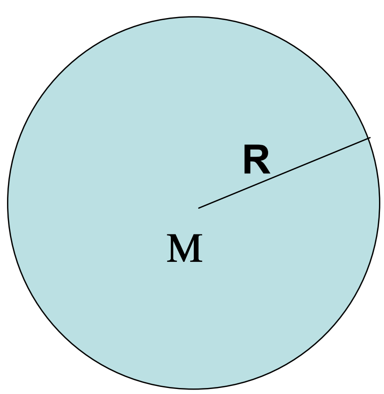
SOLAR NEUTRINO EXPERIMENT (1966)

BINARY X-RAY SOURCES (1962)

PUSARS (1967)

GAMMA RAY BURSTS (1973)

QUASI – EQUILIBRIUM OF STARS



$$\rho \sim M / R^3$$

$$kT \sim \frac{GM}{R} m_p$$

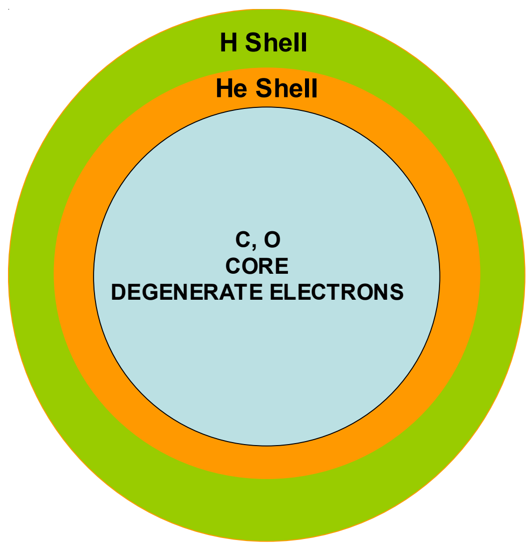
$T_c(^0K)$ 10^7 10^8 10^{9} 10^{10}

H $\longrightarrow$ He $\longrightarrow$ **C, O** $\longrightarrow$ **Si, Mg** $\longrightarrow$ **Fe, Ni**

ρ_c(gm/cm3) $\sim 10^2$ $\sim 10^6$ $\sim 10^9$ $\sim 10^{14}$

QUASI – EQUILIBRIUM OF STARS

- STARS ARE RESPONSIBLE FOR MANUFACTURING CHEMICAL ELEMENTS
- HISTORY OF A STAR IS CHARACTERIZED BY A CONTINUED CONTRACTION OF ITS CENTRAL REGIONS WITH HALTS CAUSE BY SUCCESSIVE NUCLEAR ENERGY GENERATION, PROGRESSIVELY THROUGH BURNING OF HYDROGEN, HELIUM, CARBON, OXYGEN, NEON, SILICON.. UNTIL NUCLEAR STELLER EQUILIBRIUM PEAK IS REACHED AROUND IRON
- EVOLUTION OF ATOMS IS CLOSELY LINKED WITH EVOLUTION OF STARS.



LIMITING MASS FOR WHITE DWARFS

(CHANDRASEKHAR LIMIT)

$M_{Ch} \simeq (\hbar c/Gm_p^{2})^{3/2}\, m_p \simeq 1.4\, M_\odot$

$\hbar$ = Planck constant

G = Gravitational constant

c = Speed of light

m_p = Mass of proton

Chandrasekhar's limiting mass for white dwarfs elegantly combined Special Relativity with Quantum Physics.

FORMATION OF COMPACT OBJECTS

MASS RANGE	LIFETIME (years)	REMNANT
$M / M_\odot$ # 0.7	$\sim 10^{10}$	BROWN DWARFS
0.7 # $M / M_\odot$ # 8	$\sim 10^{9}$	WHITE DWARFS
8 # $M / M_\odot$ # 20	$\sim 10^{7.5}$	NEUTRON STARS
20 # $M / M_\odot$	$\sim 10^{7}$	BLACK HOLES

ENERGY SOURCES FOR STARS

- **GRAVITATIONAL**

  $E_{grav} = - GM^2 / R \sim -4 \times 10^{48}$ erg

- **THERMAL**

  $E_{thm} = (3k\, T/2\, m_H)\, M \sim 2 \times 10^{48}$ erg

- **NUCLEAR**
  $E_{nuc} = 0.008\, Mc^2 \sim 10^{52}$ **erg**

- CAPTURE OF MATTER (ACCRETION)

REBIRTH OF STARS

IF SUN-LIKE STARS WERE TO COLLAPSE TO FORM A NEUTRON STAR / BLACK HOLE, GRAVITATIONAL ENERGY RELEASED

$\sim - GM^2 / R_{NS/BH} \sim - 3 \times 10^{53}$ erg

IN THE COLLAPSED STATE COMPACT OBJECTS LIKE NEUTRON STARS, BLACK HOLES ARE ENDOWED WITH MORE ENERGY IN THEIR SECOND LIFE THAN BEFORE.

Gravitational Energy → Rotational + Magnetic Energy
↓

RAPID ROTATION AND HIGH MAGNETIC FIELDS UNDERLIE MOST EXCITING PHENOMENA IN HIGH ENERGY ASTROPHYSICS

VITAL STATISTICS

	Sun	White Dwarf	Neutron Star	Black Hole
Radius (km)	700,000	7,000	10	3
Mean density (gm/cm^3)	1	10^7	10^{14}	2×10^{16}
Rot. Speed (radians/sec)	3×10^{-6}	3×10^{-2}	$2 \times 10^2 - 10^4$	-
Magnetic field (Gauss)	1	10^7	$10^{12} - 10^{16}$	-
Efficien. of Grav. Energy Release ($\in = GM / Rc^2$)	10^{-6}	10^{-4}	$10^{-2} - 10^{-1}$	$6 \times 10^{-2} - 4 \times 10^{-1}$

Increasing role of strong gravitational fields in controlling the energetic phenomena in astrophysics was recognised soon after a succession of discoveries such as violent events in the nuclei of galaxies (AGNs), QUASARS, Pulsars, CMBR, X-rays, g-rays and Cosmic rays.

$\odot$

Double PULSAR PSR J0737-3039

Period (P)	22.7 ms
Eccentricity e)	0.088
Orbital Period (T)	~2.4 hrs
Mass of Pulsar (Mp)	1.34 $M_\odot$
Mass of companion (Mc)	1.25 $M_\odot$

Rate of energy radiated in the form of gravitational waves

$$L = \frac{32\ G^4 M_p^5\ (M_c/M_p)^7}{5\ c^5\ a^5\ (1+M_c/M_p)^4}\ (1+73/24\ e^2+37/96\ e^4)(1-e^2)^{-7/2}$$

(a = semi major axis, e = eccentricity)

SPECTRUM OF BLACK HOLE MASSES IN THE UNIVERSE

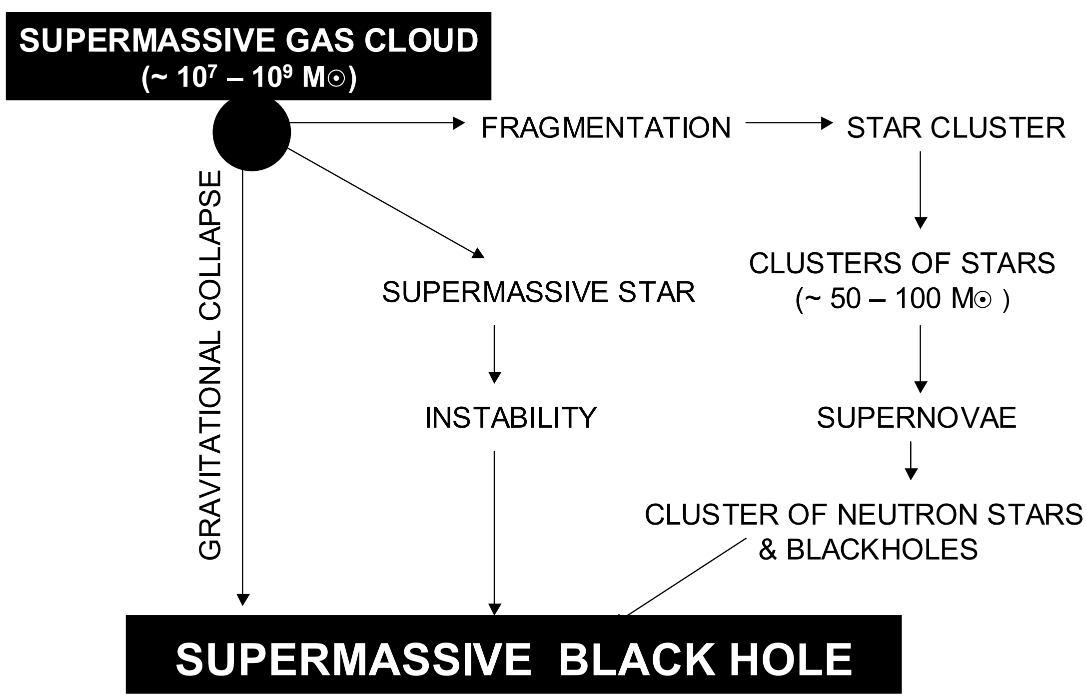
- PRIMORDIAL BLACK HOLES
- GALACTIC BLACK HOLES FORMED DURING CONDENSATION STAGES
- MASSIVE / SUPERMASSIVE BLACKHOLES FORMED AS A RESULT OF IMPLOSION OF (SUPER) MASSIVE STARS
- BLACK HOLES RESULTING FROM EVOLUTION OF DENSE STAR CLUSTERS
- ASTROPHYSICAL STELLAR MASS BLACKHOLES AS END-PRODUCT OF THERMONUCLEAR EVOLUTION OF MASSIVE (> 20 M_8) STARS

$$\rho = \frac{3\ c^6}{32\pi G^3 M^2} = 2.5 \times 10^{16}\ (M_\odot/M)^2\ \text{gm/cm}^3$$

SIGNATURE OF BLACK HOLES

- HIGH EFFICIENCY OF GRAVITATIONAL ENERGY RELEASE THROUGH DISK ACCRETION ONTO MASSIVE BLACK HOLE.
- RAPID TIME VARIABILITY OF INTENSITY OF AGNs INDICATING A COMPACT ENGINE AS A SOURCE
- CHARACTERISED BY PRESENCE OF SUPERLUNINAL JETS.

ONCE A LARGE ENOUGH MASS HAS BECOME CONCENTRATED WITHIN SUFFICIENTLY SMALL VOLUME, A RUNAWAY PROCESS LEADING TO EVENTUAL FORMATION OF MASSIVE BLACK HOLE IS INEVITABLE



CENTERS OF GALAXI ESHARBOURING SMBH

- MILKY WAY (2 – 3) x 10^6 $M_\odot$
- M 87 2.5 x 10^9 $M_\odot$
- NGC 4258 3.6 x 10^7 $M_\odot$
- M 31
- M 32
- NGC 3377
- NGC 459
- NGC 3379

GAMMA RAY BURSTS (GRBs)

- GRBs accidentally discovered in late 1960s military VELA satellites monitoring atmospheric nuclear explosions.

  (BATSE, COMPTON GRO, BeppoSAX)

  Cosmological origin of GRBs with energy

  $\sim 10^{52} - 10^{53}$ erg.

  For a few seconds GRBs are the most dazzling objects in the sky outshining rest of the universe with intense burst emission in KeV – MeV range, lasting for ~ 30 microsec to hundreds of seconds and occurring at the rate of ~ 1000 per year.

  Afterglow discovered in radio, optical, X-ray bands.

  Steller mans compact objects are the central engines driving GRBs.

  Merging neutron stars / black holes

  Hypernovae resulting from collapsed massive stars.

COLLAPSED OBJECTS AND ASTROPHYSICAL PHENOMENA

- RADIO PULSARS : ROTATI NG NEUTRON STAR PROVIDING THE STABLE CLOCK MECHANISM
- BINARY / DOUBLE PULSARS : PAIR OF NEUTRON STARS ACTING AS GARAVITATIONAL RADIATION TRANSMITTER
- X-RAY BINARIES : NEUTRON STAR / BLACKHOLE WITH MASS LOSING COMPANION
- GAMMA RAY BURSTERS : MERGING NEUTRON STARS / BLACKHOLES

  HYPERNOVAE
- AGNs / QUASARS : POWERED BY DISK ACCRETION OF GAS ONTO SUPERMASSIVE BLACKHOLES IN NUCLEI OF GALAXIES

- Observational astronomy went through a technological renaissance with the universe being simultaneously surveyed through a range of windows from radio to gamma rays.
- Will the advances made during this golden age of astronomy be matched by even more exciting discoveries in this millennium?
- Has astronomy any future now that the Universe has been glimpsed through most of these windows?

Outstanding problems in Astrophysics

- Solar neutrino puzzle, paradox, conundrum
- Seat and operation of solar dynamo
- Nature of central engines and underlying mechanisms driving energetic events such as supernovae, GRBs, AGNs (QUASAR), ultra-high energy cosmic rays
- Unambiguous signature of putative massive black holes lurking in centres of galaxies
- Coherence of well collimated jets associated with young proto-stars, X-ray binaries, AGNs over different length scales from pc to hundreds of Kpc.
- Original of angular momentum and magnetic field in the Universe
- Nature and distribution of dark matter and dark energy in the cosmos – structure formation in the Universe
- Ultimate fate of the Universe
- Are there parallel universes or is it all a cosmic illusion !

Einstein's Ideas in every Day Life

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Einstein's influence is far and wide, it is not limited to the theory of Relativity and its consequences. Einstein's ideas are playing an important role in our day to day life. Many modern technologies are based on some principles discovered by Einstein. His descriptions of how light acts as particles called photons, how atoms emit radiation and how velocity and gravity affects clocks are all important to make the common devices work. We shall have a glimpse of how Einstein's ideas are playing an important role in our day to day life.

PHOTOELECTRIC EFFECT

The photoelectric effect was observed as far back as 1839, in France. The current wave theory could not explain the phenomenon. Einstein correctly explained it, in one of his papers published in 1905. Einstein proposed that light consists of particles rather than waves. Afterwards these particles were named as photons. When light is allowed to incident on certain substances electrons are liberated. If intensity of incident light is increased, more number of electrons are emitted but their energy remains the same. Energy of liberated electrons increases with increase of the frequency of incident light. This is obvious because the energy of a photon is proportional to its frequency. Einstein was awarded Nobel Prize in 1921, for this very explanation of photoelectric effect. Modern technology is exploiting the properties of photoelectric effect. Following is list of some of the gadgets based on this effect.

- Photographic and video cameras
- Charged coupled devices (CCD)
- Image converters and inverters
- TV camera tubes
- Pointers and Sensors
- Light vision scopes
- Solar cells and solar panels
- Photometers

LASER

LASER is a short form of 'Light Amplification by Stimulated Emission of Radiation'. The laser owes its existence to a theoretical framework erected by Einstein in 1917. In that year he published a paper 'On the Quantum Theory of Radiation'. The seeds of modern lasers can be found in that paper. Atoms can be excited if they absorb light. They spontaneously emit light to return to a lower level. In addition to absorption and spontaneous emission, Einstein deduced that a third kind of interaction must exist, one in which a photon could induce an excited atom to emit another photon. These two photons in turn could stimulate two other atoms to emit photons, and so on.

Although Einstein's equations state that stimulated emission produces additional photons, they do not explicitly indicate that it produces exact copies, identical not just in frequency but also in phase. This means that all emitted photons are coherent. The trick of creating a coherent beam was to establish a ' population inversion' that is making more atoms excited than not excited. This was achieved in 1954 by Charles Townes . He devised the laser's predecessor, the ‘maser’. (Microwave amplification through stimulated emission of radiation) The laser was invented by Theodore Maiman in 1960. Since then Laser has captured many fields of modern technology. Following list will give some idea of how laser has spread its tentacles.

- Accurate measurement of Earth Moon distance
- Encode digital information on audio and video discs.
- Precision etching drilling and cutting metals.
- Eye surgery (Minimal invasive procedures in medicine)
- Welding cutting sealing ablating and coagulating tissues
- Unclogging obstructed arteries
- Breaking kidney stones
- Clearing cataracts
- Altering genetic materials
- Long distance transmission of signals for communication
- Accurate measurement of distances and time intervals
- Laser based weapons

BROWNIAN MOTION

The year 1905 is called miraculous year in the life of Einstein. In this year only Einstein published 5 scientific papers. All of them proved to be revolutionary. A paper on Brownian motion was one of them. Random motion of particles suspended in liquids is called Brownian motion. In those days molecules of liquids were not known. Einstein assumed their presence and suggested that the molecules of liquids collide with the suspended particles in all directions. The result is random motion of the particles. Einstein even tried to find out the dimensions of the molecules. Results of the Einstein’s calculations are now applied in various fields listed below.

- Fractals (Random iteration algorithms)
- Medical imaging
- Robotics
- Estimation of extreme floods and draughts
- Market analysis
- Stock markets
- Manufacturing
- Decision making
- Aerosol particles

GLOBAL POSITIONING SYSTEM (GPS)

Global positioning system consists of 24 satellites revolving around the Earth. With the help of GPS receiver anybody can find his accurate position on Earth. The receiver indicates latitude, longitude, height above ground and universal time. In order to get correct readings two relativistic corrections should be applied. First correction is due to very fast motion of the satellites. According to relativity time slows down due to speed.

This correction amounts to about 8 microseconds. Second correction is due to reduced gravity at the height of the satellites. According to relativity clocks run fast in low gravity. This correction amounts to 45 microseconds. Thus net relativistic correction is 45-8 = 37 microseconds. Without these corrections the readings would have gone wrong by several kilometers. GPS satellites have found their application in numerous fields.

- Search and rescue operations
- Ships monitoring system
- Hydrographic survey
- Spacecraft launch and landing
- Navigation
- Weapons guidance and control
- Photoreconnaissance and intelligence gathering
- Surveying and mapping
- Transportation and communication
- Airport approach and landing
- Aerial photography
- Open ocean and costal navigation
- Map updating
- Seismology
- Meteorology

EINSTEIN'S MASS ENERGY EQIVALENCE (E = m c square)

'E = m c^2' is Einstein's most famous equation. He proved this mass energy equivalence in his miraculous year i.e. in 1905. Since the multiple of the mass is square of velocity of light, which is '9x10^16 ', it is obvious that a very small mass will yield tremendous amount of energy if it is completely converted in to energy. This is the principle of atomic bombs and nuclear power generation. Besides that the phenomenon has several other applications, such as,

- Powers the Sun therefore life on Earth
- Keeps Earth's crust warm
- Provides study of matter and antimatter annihilation
- Powers the satellites from Plutonium
- Proposed radiation pressure driven spaceships
- Proposed fusion reactors
- Study of high energy particle physics
- Radio isotopes used in medical imaging and radio therapy
- Power from fission reactors: Nuclear power plants
- Nuclear weapons: Atom and hydrogen bombs

SPINTRONICS

For stability of atom relativity demands that the electrons moving round the nucleus should also spin. This fact can be exploited to create new version of electronic circuits. Already silicon chips are reaching their limits. Connections are coming so close that the quantum effects will not allow the circuits to function properly. The electrons will start jumping across the connections. New technologies are now searched. That can replace silicon chips. One such alternative is Spintronics. An electron can spin ‘up’ or ‘down’. One of its positions can be assumed to be ‘1’ and another ‘0’. Thus logical circuits can be built using this property of an electron. Efforts are being made in this direction. Already some applications are visualized as follows

- Semiconductor devices: Transistors, IC, LED, Lasers, CPU, Processors
- Magnetic devices
- Non volatile memory
- Storage
- Magneto optical devices
- Optical isolators

BOSE EINSTEIN CONDENSATION

When atoms are cooled very close to Absolute zero, the waves associated with the atoms overlap each other. In that case all atoms together behave as a single atom. A so called ‘super atom ‘is formed. This is called ‘Bose Einstein Condensation’. Now Bose Einstein Condensation is treated as the 5th state of matter. It offers a clearer window than we have ever had before onto the weird world of Quantum Statistical Mechanics.

We know that speed of light reduces when it passes through a transparent medium. For example speed of light in glass is about 200,000 km/sec. If a beam of light is allowed to pass through Bose Einstein condensate, it is completely stopped within the super atom. In fact if the beam carries information, it can be completely recovered, when the same is allowed to emerge out of the condensate. This property can be utilized in future. Following are some of the proposed applications of BEC.

- Creation of Atom Laser, that can be used in;
    1. Atom optics
    2. Atom lithography
    3. Precision atomic clocks
    4. Holograms
    5. Communication and Computation
- Storage devices
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Albert Einstein : Man and Scientist

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That very name Einstein, evokes wonder and awe; wonder for the astonishing miracles of his science, his Relativity theory, the energy and mass formula, $E=mc^2$, which allowed man to touch the throbbing heartbeat of the sun, the notion of photons and photo electricity, which led others to discover the solar power cell and the laser. Almost any one of his discoveries would have earned him universal admiration and respect. But for one lone man, using the limitless creativity of mind to envisage the twisting eddies and warps of time, space and gravity, Einstein's achievements become truly awesome.

Who was this man who was perhaps called the greatest scientist of all times and why was he so respected, admired and even loved, by almost the entire world ?

Einstein was fond of telling the story about his childhood, when four or five years old. The family - his father Hermann, Mother Pauline and sister Maja, two years younger than he, were living in Munich at that time. As the story goes, young Albert had been ill and in bed and his father brought him a small compass to play with. Many children have palyed with such a toy compass but for young Albert the effect was extraordinary. For, as Einstein recalled later, here was a tiny needle isolated and unreachable behind its glass cover, a needle that was mysteriously caught by an invisible force that made it point towards the North Pole. To Albert Einstein that simple toy compass was a revelation and he wrote in a letter : ''Outside events capable of determining a person's thoughts and actions probably occur in everyone's life. But with most people such events have no effect. As for me, when I was a little boy, my father showed me a small compass and the enormous impression it made on me certainly played a role in my life.''

Einstein was born in Ulm, Germany on March 14, 1879. A year later his father moved his family and his electrochemical business to Munich and it was there that young Einstein grew up. By instinct young Albert was a loner. His sister Maja recalled later that he preferred to play by himself and he enjoyed games that required patience and perseverance. He did not learn to speak until he was three years old. Einstein grew to be good in the subjects he was interested in, but hated things that required a lot of memorization like languages, Botany and so on. On teacher harshly concluded about Albert Einstein, ''you will never amount to anything.'' But in mathematics and physics, Einstein was far beyond the school curriculum, and that was as much due to his sense of wonder and curiosity as to his independent study of the subject.

His love for music, mathematics and physics was joined by another love, something he called holy geometry. When he was merely twelve, he came upon a geometry text book and read it avidly. He was amazed at the fact that one started with axioms that couldn't be doubted and through simple arguments emerged amazing theorems. He realized that in order to make a transition to physics, one has to begin by grasping some universal truths and then proceed from there; and not by merely collecting facts for it may not be possible to piece them together.

At the age of fifteen, his father's business began to fail and Hermann Einstein moved his family to Italy. They left Albert behind so that he could get his high school diploma but Albert found himself unhappy and lonely. The teachers did not like him and one of them asked him to leave the school. Einstein was happy to leave and went to visit his family in Italy. He roamed the country with a friend and wallowed in the warm temperaments of the Italians, so different from the Germans.

In the year 1900, he graduated from the Zurich Polytechnic and became a Swiss citizen, in 1903, he married his old classmate Mileva Maric. Because of his forthrightness and distrust of authority he had alienated his professors, who might have otherwise helped him to get a job. He was reduced to taking odd jobs such as as that of a part - time teacher. It was his old friend Marcel Grossman, who saved the situation. He pulled strings with the head of the patent office at Zurich, to get him a job there. Einstein worked at this office for seven years

The year 1905 was a year of incredible achievements for the twenty six year old patent examiner. He published a paper entitled : ''On the electrodynamics of moving bodies ''which became known as Einstein's Special theory of Relativity.

Also in 1905, Einstein introduced an idea, quite revolutionary at that time, that light can sometimes have characteristics of particles. And it was these particles, or photons as they are called, which knocked out electrons of metals (Photoelectric effect.)

Einstein wrote in a letter that the motivation of his scientific work was an irresistible longing to understand the secrets of nature. In all his work, he was striving to find the least complicated way to explain the universe.

When the first World War broke out in August 1914, Einstein was at work on his General theory of Relativity, and in 1915 he published his thesis. General Relativity predicted that when light from a distant star passes close to the Sun, on its way to the Earth, the intense gravity of the solar disc would bend the light.

The news was electrifying to a world weary with death and destruction. Overnight Einstein became famous. Reporters from newspapers beseeched him for interviews. The popular acclaim was as puzzling to Einstein as his theory was to the public ! He wrote to a friend : ''With fame I became more and more stupid, which is a very common phenomenon. There is far too great a disproportion between what one is and what others think one is, or at least what they say they think one is. But, one has to take it with a good sense of humour.''

With his shaggy hair and rumpled clothes, Einstein did not fit the stereotyped image of the world's greatest scientist. But most of all there was a sense of humour especially when describing himself. Consider the letter he wrote to a young relative, upset because he had not visited her house. Einstein wrote :''Dear Miss Ley, I hear that you are dissatisfied because you did not see me. Let me therefore tell you what I look like : pale face, long hair, and a tiny beginning of a paunch. In addition an awkward gait, a cigar in the mouth - if I happen to have one, a pen in pocket or hand. But crooked legs and warts I do not have, and I am quite handsome. Also, no hair on my hands such as is often found in ugly men. So it is indeed a pity that you did not see me. With warm greetings, Yours uncle Einstein.''

In 1921, Einstein won the Nobel Prize - his only Nobel award for his work on the photoelectric effect. There was no mention in the official citation of the Relativity theory that was regarded as too controversial, both scientifically and culturally.

In Germany, meanwhile, there were the first stirrings of fascism and anti-Semitism. Jews were being blamed for Germany's loss of the first World war, and Einstein himself was under attack. He was always outspoken in his opposition to German militarism, and neither his pacifism nor his world wide fame could stop the harassment he was subject to. Einstein spent much of his time abroad teaching, and when Hitler came to power in Germany in 1933, he made his final break with his homeland.

As the threat of war in Europe approached, there were growing worries that the Nazis might be trying to develop an atomic bomb. Einstein had no role in the actual development of the bomb but was forced to lend the prestige of his name to it in 1939. The rest is history. The bomb was developed and was used. When it was dropped on the Japanese, Einstein was horrified and said that had he known before, as was discovered later, that the Nazis had given up the attempt to develop the bomb, he would not have had anything to do with it.

Life slowed down for Einstein after 1950. He worked for nuclear disarmament and continued to speak out strongly against attempts to curb freedom. In the last years, Einstein worked steadily at the Institute for Advanced Studies, Princeton, New Jersey. He was searching for the elusive. 'Unified Field Theory', to explain and unite the forces of gravitation and electromagnetism. He was not successful. But as wrote to a friend,'' I still struggle with the same problem as ten years ago. I succeed in small matters, but the real goal remains unattainable even thought it seems probably close. It is hard, and yet rewarding. Hard because the goal is beyond my powers, but rewarding because it makes one immune to the distractions of everyday life.''

Einstein died on April 18, 1955. The entire world mourned his passing. Shortly after his death, newspapers carried a small drawing by a political catoonist Herblock. It showed a tiny planet Earth lost amidst the stars. Attached to the side was that said simply,'' Albert Einstein lived here.''

Science Fiction based on Einstein Theories

''There is no perfect theory but there can be a successful theory because no matter how many experiments agree with it, if one proves it wrong than the theory is wrong. The only way a science can progress is by proving a theory wrong. When a fact doesn't fit a theory there is a urgent need to either patch it or discard it. For wrong theory a scientific theorist is not be envied. For nature ** is an inexorable and not very friendly judge of his work. It never says a ''yes'' to a theory. In very best case, it says 'May be' and in great majority of cases simply 'No'.

The world we live is stranger than fiction. It seems strange that living creatures who believe themselves is the most intelligent are unable to know even their own origin in time span of more than 2000 years. The science, humans have developed is inconsistent. There is one theory that explains one phenomenon precisely but fails completely at the either. The science of today is successful in making things more complicated than rather making it simpler.

Albert Einstein, the science icon of the century revolutionized the entire physics. He changed the way we think about space and time. His two theories published in 1905 A. D. called special relativity (S. R) and general relativity (G. R) seemed fiction to the world initially and very few physicist accepted it. These theories were way apart from our thinking. But now this is the theory that has formed the base to what we call as modern physics or quantum physics. It solved the biggest challenges of physics such as answer to Michelson-Morley experiment and getting rid of other, explaining that even time is relative and that time travel is possible through time dilation phenomenon. Showing that gravitational leansing could allow us to see magnified image of most distant galaxies and much more.

Science fiction means assumption without proofs. The S.R. and G.R. can be rightly said as completion of Newtonian classical physics. Einstein, the most celebrated scientist of twentieth century, remain an icon of power, of human reason to penetrate mysterious nature for billions of people who have been taught the essence of his relativity theories, he changed (or muddled) their very conuption of time and space. He destroyed the common sense concept of universal now-the absolute simultaneity of events in different relatively moving reference It could be said that theory was almost next to perfection. The scientist even today are trying to find Grand Unified Theory (G.U.T) on basis of relativity.

Even though the theory had roaring success the theory left behind a very few doubts that are yet not verified. This unexplained staff unless successfully found agreeing with relativity would eventually tend to declare relativity as an incomplete theory rather than proving it wrong. Einstein himself at various times had expressed doubts about the edifice of modern physics that he had helped to create – witness the remarks that fovour perhaps his most serious expression of doubt come in 1954 letter, the year before he died, to his friend Michel Besso : I consider it quite possible that physics cannot be based on the field concept i.e. on continuous structures.

Here I am going to suggest the discrepancy in relativity and alternative theories which could resolve them. These are purely my own views and the outcome of my thinking, you could tell it as research work on S.R. and G.R. They are none less than fiction because eventhough some aspects have mathematical proofs but they are not verified experimentally.

PROBLEMS WITH RELATIVITY : (Conclusion)

1) Relativity suggest that nothing that can transmit information could crose speed of light. But speed of gravity can't be less than that of light in vacuum. The best example to explain this is that in black hole the escape speed from event horizon is greater than 'C', hece black hole must not exert any gravitational field. This is contrary to observation suggesting speed of gravity must be greater that 'C'.

2) A movement or change can only be defined when we mention an observer. Hence there is no absolute motion. So concept of absolute motion is to be discarded as that of absolute space and absolute time.

3) There is no change in universe in absolute terms. Universe is as it as it was. Even its expansion is not spared. It's expansion can't be in nothing. Thus the expansion is only illusion in absolute terms.

4) Only matter and energy in Universe is moving apart with respect to other matter and energy. It's boundaries aren't expanding.

5) Relativity suggest the relativisic effects are proportional to its relative speed or velocity but not with respect to its acceleration.

6) Light early speed may be less as compared to 'C'. Moreover light suffers bending in intense Gravitational field Resulting sometimes in gravitational lensing. So light alone can't be used to predict the age of universe.

7) As energy causes subatomic particles to raise to higher energy level the force tends to increase the masses of the body as they approach the speed of light.

8) According to relativity we can't predict which length is larger unless the we know it's relative speed w.r.t. to us.

9) Relativity suggest that light speed can't be exceeded hence the warp drives, warm hole and super luminance theory are not supported by it.

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