SPACE - TIME - GRAVITATION

Vladimirov et al

- The future is always vaster than the past, since the tiny bag of assimilated knowledge is a drop compared to the enormous ocean of the unknown. "The whole of ~~Physics~~ Science is nothing more than a refinement of everyday thinking" Einstein
- Coulomb's law modelled after Newton's gravitation potential formula.
- A theory is conceived by assimilating the information Man accumulates in the course of his practical activities
- * Euclidean geometry - high level of intellectual activity - far above contemporary low primitive levels of technology and experimentation.
- logical reasoning led to new statements - real facts
- Recognition of affinity between - ~~Electro~~ mechanics, Electromagnetism, gravitation - later quantum theory
- An experiment does not produce either a formula or principle that makes a theory intuition of the theorist most important creative tool.
- Dirac's Dictum: Physical Laws Should have mathematical beauty.
- Is Euclidean geometry mathematics or physics? Euclidean geometry describes the world around us and exists as an objective system of of knowledge. Therefore, it must be classified with theories of physics.
- All phenomena due to General Relativity were first predicted by theory. (What about Gravitational Lensing?)

'Space' - Everyday experience - meaning attached to Concept of Space and time
The "emptyness" in between things -
Space and time in elementary Scale. -
intervals - units .. etc.
Classical physics - Velocity, acceleration, ...
3 dimensions of Space + One dimension of time.
Causality - contiguity of Space and time

- Motion and dynamics

Space and time - Same everywhere in the Universe - Only one meter Stick and one clock.

- Geometry - Euclid (300 BC) -
Space is Euclidean. - the Sum of the three angles of a triangle equals 180°.
Straight line is the Shortest distance between two points. ..

Advent of Relativity - Lorentz Contraction. } Dilatation of Time } Motion. -

dependence of Space and time on
Constancy of velocity of light.
Relativistic Mass Increase.

Structure of Matter - Look from a Microscope -
Emptiness abounds. 99.999.. is all Space, emptiness.

Size of an Atom ≈ 10^{-8} cms } Empty Space in between
Size of Nucleus ≈ 10^{-13} cms } $10^{-24}/10^{-39} \approx \underline{\underline{10^{15}}}$

Size of Molecule ≈ 10^{-5} cms

The atom occupies roughly 1 part in 109 of the volume of a molecule.

{ The nucleus occupies 1 part in 10^{15} of the Space inside the atom.

These empty Spaces are filled with Fields.
But what are these fields?

Def. by Hawking — Something that exists throughout space and time, as opposed to a particle at only one point at a time

Fields - Magnetic, Electric, E.M. } Connected with the idea of **Forces**
Gravitational, Weak, Strong }

- Newton and Gravitational force -
  Action at a distance ? How? God only knows.

- Faraday } Concept of a force replaced by
  Maxwell } that of **force field**

Instead of saying attract each other or Repel each other
F and M : Each charge creates a 'disturbance' or a 'Condition' in **Space** around it so that the other charge feels a force. The condition in space which has the potential of producing a force is called a field.

This had profound impact on conception of **Physical Reality**.
Newton had connected force with material bodies
The new concept of field gave a meaning to field as a Reality.
Field could be there by itself - EM field -

- Maxwell tried a mechanical interpretation - States of mechanical stresses in **ether** and EM waves as elastic waves in ether - but failed.
- Einstein : ether was abandoned. Space became supreme.

Four dimensional Space-time Continuum.
No universal absolute time.
New Framework for the explanation of nature.
Mass = Energy ($E = mc^2$)
c is an absolute Constant

General Theory of Relativity -
Idea of Curved Space around objects.
Space-time Structure depends on distribution of matter.-
in the Universe -
Concept of 'empty space' loses meaning.

—

Rutherford's experiments - atoms are not hard Spheres and indestructable are vast regions of space with small particles moving around.
Quantum theory made it clear - even these particles are not like solid objects - abstract dual aspect wave/particle depending on how you observe.
How can something be a wave and a particle at the same time?

Analysis of processes in atomic domain show that subatomic ~~entities~~ particles have no meaning as isolated entities. They can only be understood as interconnections — a basic oneness - a web of relations between parts and whole.

- Empty Space - New vacuum - as Dirac Sea. Sea of particles and antiparticles - appearing and disappearing - within the limits of Uncertainty Principle
  Creation of pairs - electrons and positrons.
  Space - presence of everything - not absence.
  Creation of particles.
  Continuously changing nature of particles.

Maxwell
"Vacuum is that which is left in a vessel after having removed everything we can remove from it"

that about Universal Quantum Vacuum?

Slides: pair production.
Meson production.
Showers.

Creation of Space – Big Bang theory.

Modern theory of vacuum –
Quantum Field Theory
General Relativity
Mathematics

Between
Inner Circles and
Outer Circles
BARROW

Rudolf Clausius (1850)
• Entropy of a closed system can never decrease.
(Universe as a Whole)
Second Law of Thermodynamics)

backward in time →

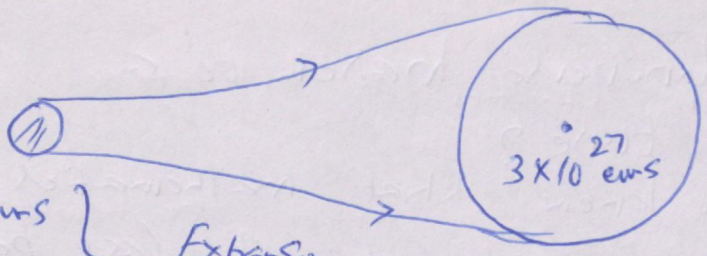
• The present disordered universe
Ordered universe of Zero or Minimal entropy –
Start of the Regime of natural laws

Eddington – Beginning of the expanding universe.

Early Universe: Calender of events

0 – 1 Second – $< 10^{-10}$ seconds – Temperature higher than that you can produce in the Lab. LHC accelerator collision of particles.

1 Second – 3 Mins Universe is a vast Nuclear Reactor – light isotopes of deuterium, He-3 He-4, Lithium-7 produced. (as observed today in relative abundance)



Visible Universe Today

3×10^{-25} cms
10^{-35} seconds
Expansion

Causally Connected patch

Expanded version of the causally connected patch today.

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Conservation Laws - of mass, energy, charge... angular momentum

Surprising feature full significance not known yet.

pose no barrier for the theory of the origin of the Universe out of nothing.

Time

- The Universe is created with time, not in time
  No transcendental time outside the Universe.

The Universe is the totality of all events and things. So may not need a cause!
Is there a deep reality called time?

'Once upon a time there was no time'

time = Oscillations of pendulum
Vibration of atoms.

no formula that can be used 'as clock' as you go back

time. Another form of Space - Hawking and Hartle

Mathematics

- Why does the Universe march to a mathematical tune?
- If you want to know what mathematics is a mathematician is probably the last person to ask
- Uncovers deepest structure of reality.
- Catalogue of all possible patterns.
- We cannot exist in a patternless chaos.
- Why are such simple patterns so far reaching in their explanatory power?
- Mathematics is the language that allows us to talk most effectively, efficiently, logically about the nature of things.
- Mathematics has become the definition of explanation in physical sciences
- Mathematical Patterns → Group Theory – Elementary Particles
- New mathematics required now (Superstring theory)
- Fractals underwrite all natural phenomena (Self-Similarity)
- Faith of the Scientist:
  ↓
  Ubiquity of Math.
  ↓
  Is God a mathematician?

Mathematics is necessary and sufficient for describing everything from the inner space of elementary particles to outer space of cosmos. – the entire Universe itself

Mystery - Why does Symbolic language of mathematics have everything to do with falling apples, splitting atoms exploding stars or fluctuating stock markets?

* What is the relation between mathematics and reality? What is the meaning of mathematics?

Hilbert: proposed that we cease worrying about meaning of mathematics. Instead he define mathematics to be no more and no less than the tapestry of formula that can be created by any set of initial axioms by manipulating the symbols involved according to specified rules

Formalism

(Hilbert and his followers did not care for the miraculous applicability of mathematics to Nature) No connection with Reality.

Godel: Showed Hilbert's thesis WRONG.

" Whatever set of consistent rules one adopts for manipulating mathematical symbols involved, there must always exist some statements framed in the language of those symbols whose truth or falsity cannot be decided using those axioms and rules.

* You have to go Outside Mathematics

* You can prove that there are Unprovable statements in the realm of mathematics

Mathematical Platonism

- Mathematics exists whether or not there are mathematicians
- There exists a world of perfect mathematical forms which are the blue prints from which our imperfect experience is derived.
- Striking parallel between mathematics and philosophical theology.
- The mathematics of the Platonist transcends the world and is viewed as existing before and after the creation of the material world.

Realism

Constructivism - Kronecker - "God made the integers, all else is work of Man"

Accept 1, 2, 3, 4, ... Simplest mathematical notions and Counting → intuition → step by step higher track.

Non-computable - the mathematical operations that a Turing machine cannot perform in finite time are called Non-Computable.

Does the action of human consciousness involve non-computable mathematics?

What is more fundamental? Symmetry or Computation? Is the universe a cosmic kaleidoscope or a computer?

Continuous vs discrete

Should we assume that the Universe does only computable things?

- Quantum Computing - beyond Turin Machine.
- The world is ultimately a quantum system

- Is it more basic to view the evolution and structure of the Universe as a computation or as the consequences of the laws of Nature. Or merging the two concepts, whether we should treat the laws of nature as though they are form of software that happens to be running upon the material content of the Universe ?

Where as the picture of laws of Nature as Symmetries and invariances so beloved by the physicists blends naturally with the Platonic view of mathematical reality, the computational picture seems to point more naturally to the more limited constructive kind

Mathematics is useful in the description of the physical world because the world is algorithmically compressible.
The brain possesses the ability to compress complex sequences of sense data into abbreviated form. These abbreviations permit the existence of thoughts and ~~forms~~ memory

The brain is an evolved complex state of the very world whose complexity it seeks to compress, albeit one that has yet to fathom its own complexity