

In fond memory of
Professor A.K. Raychaudhuri
who passed away on June 18, 2005



Why Einstein? (Had I been born in 1844 !)

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Universality

**UNIVERSAL means: Same for All,
Shared by All**

**Primary Universal Entities:
SPACE and TIME**

**Both must be on the same
footing...**

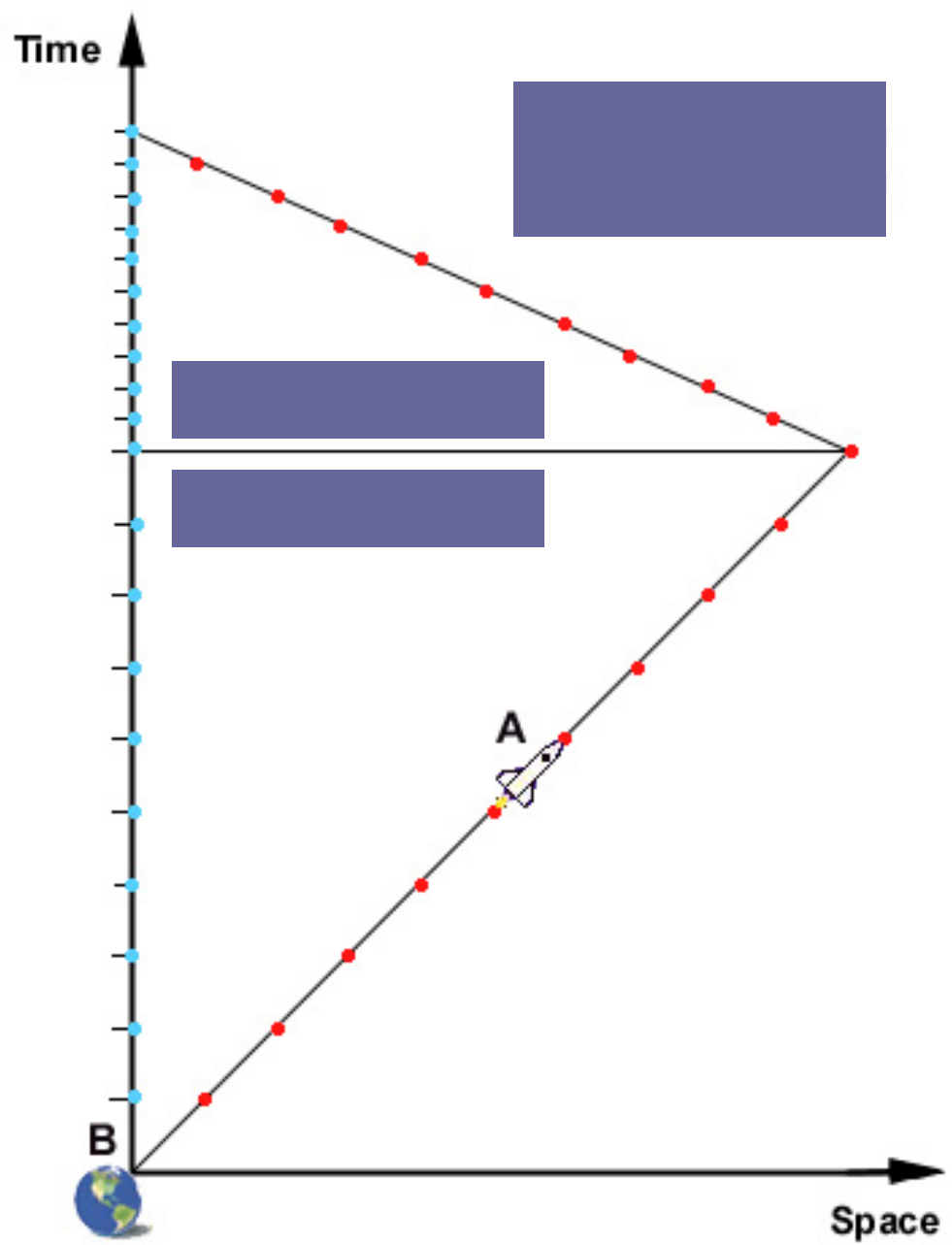


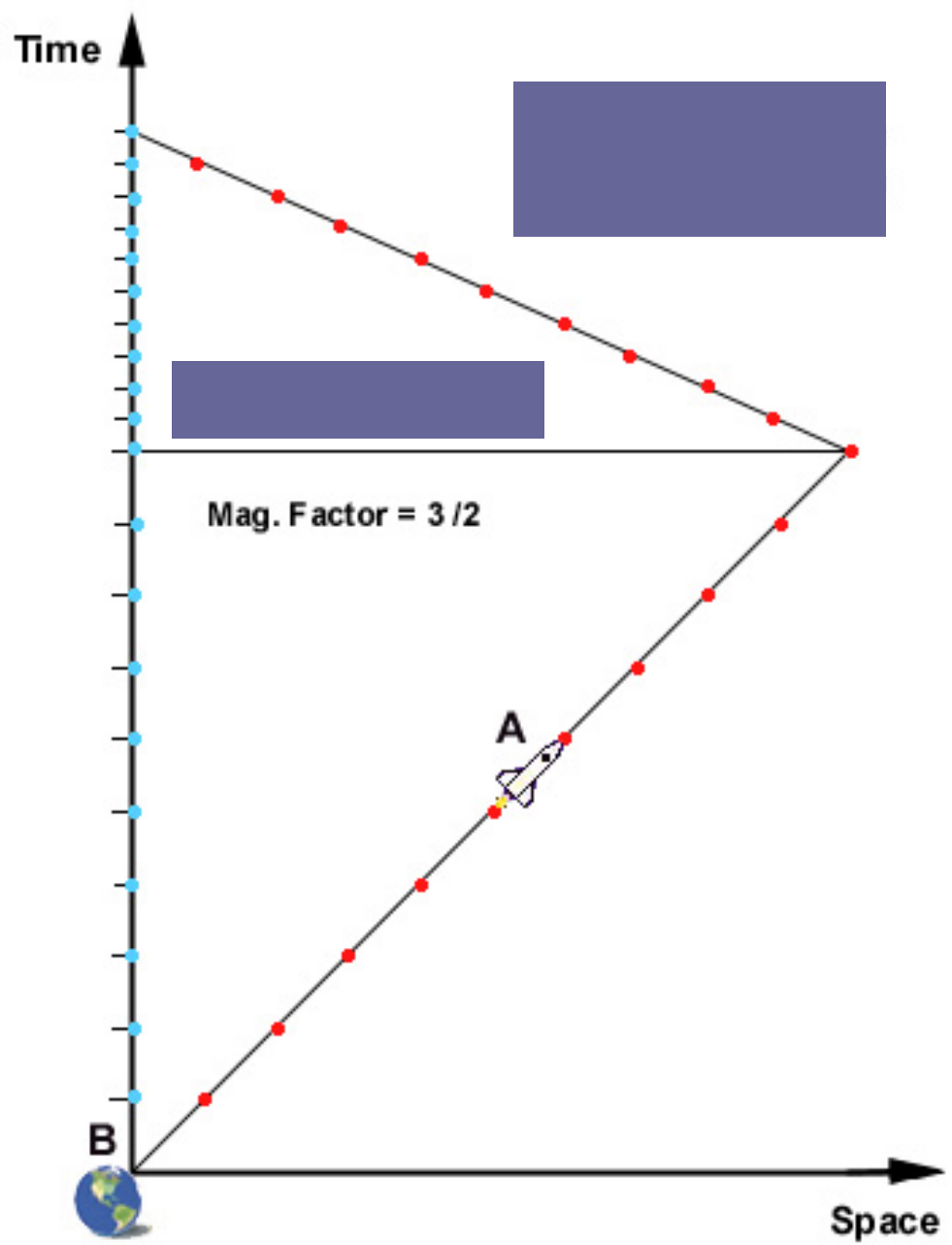
Universality

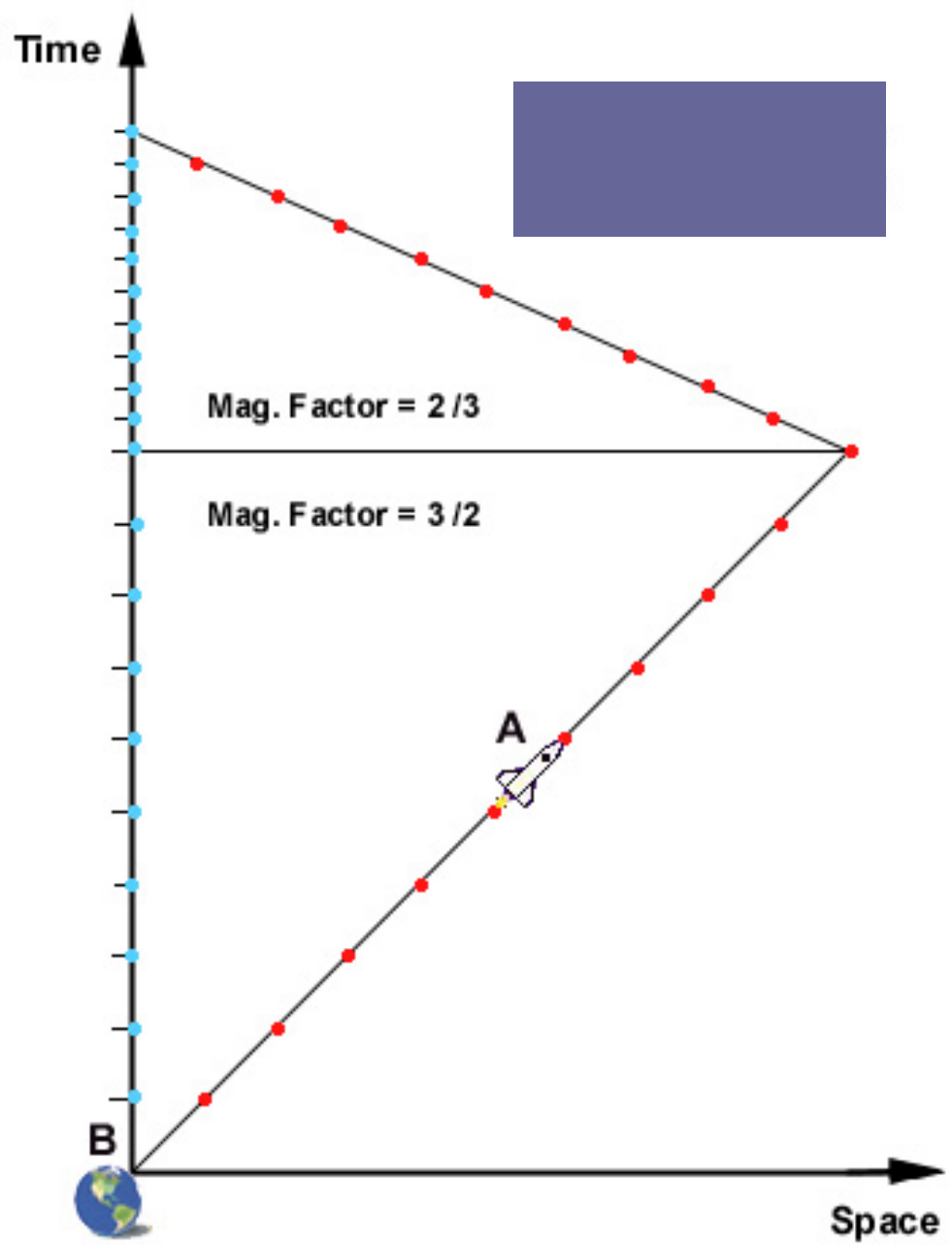
“The distance between two points is observer dependent.”

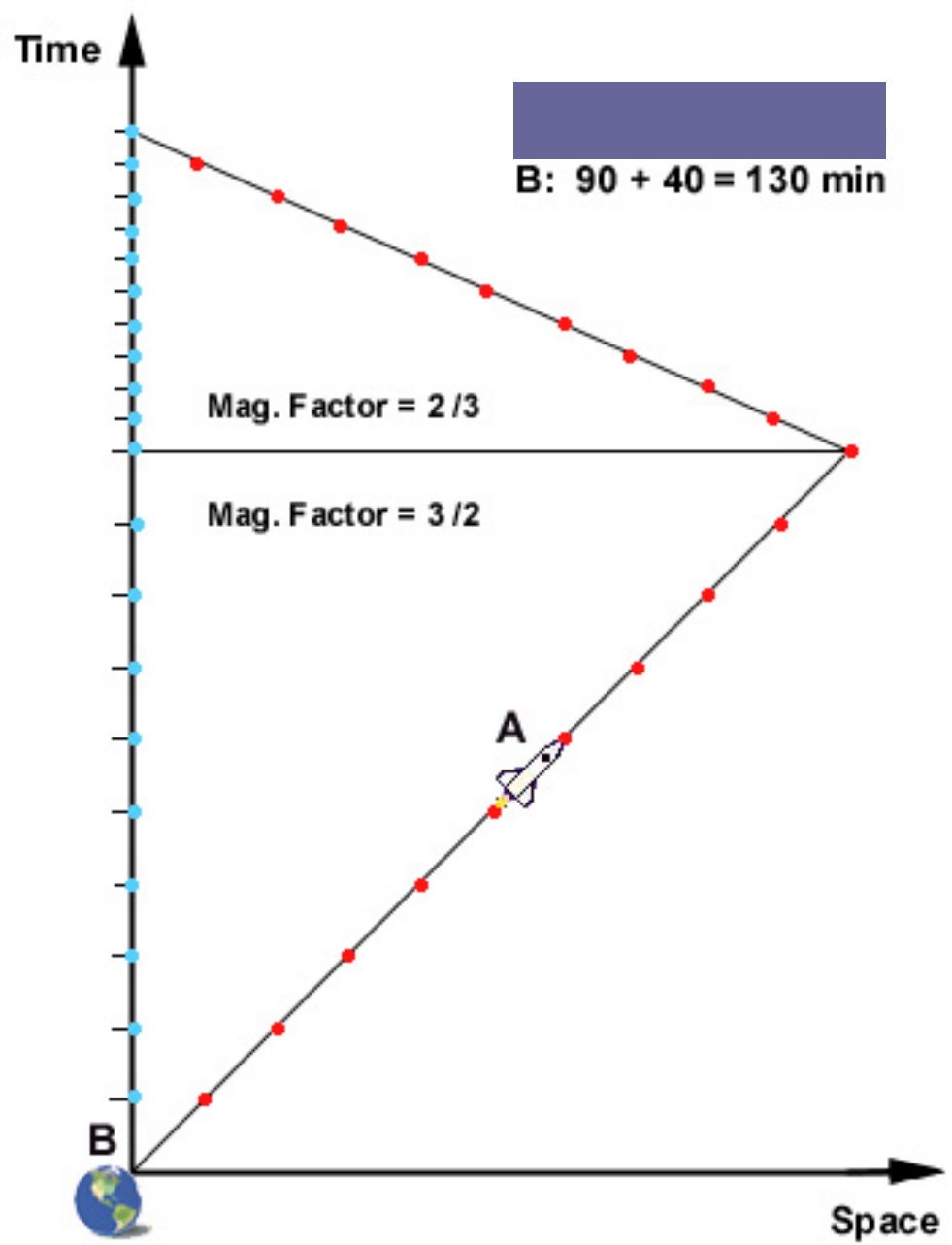
... & So must be the Time interval between Events !

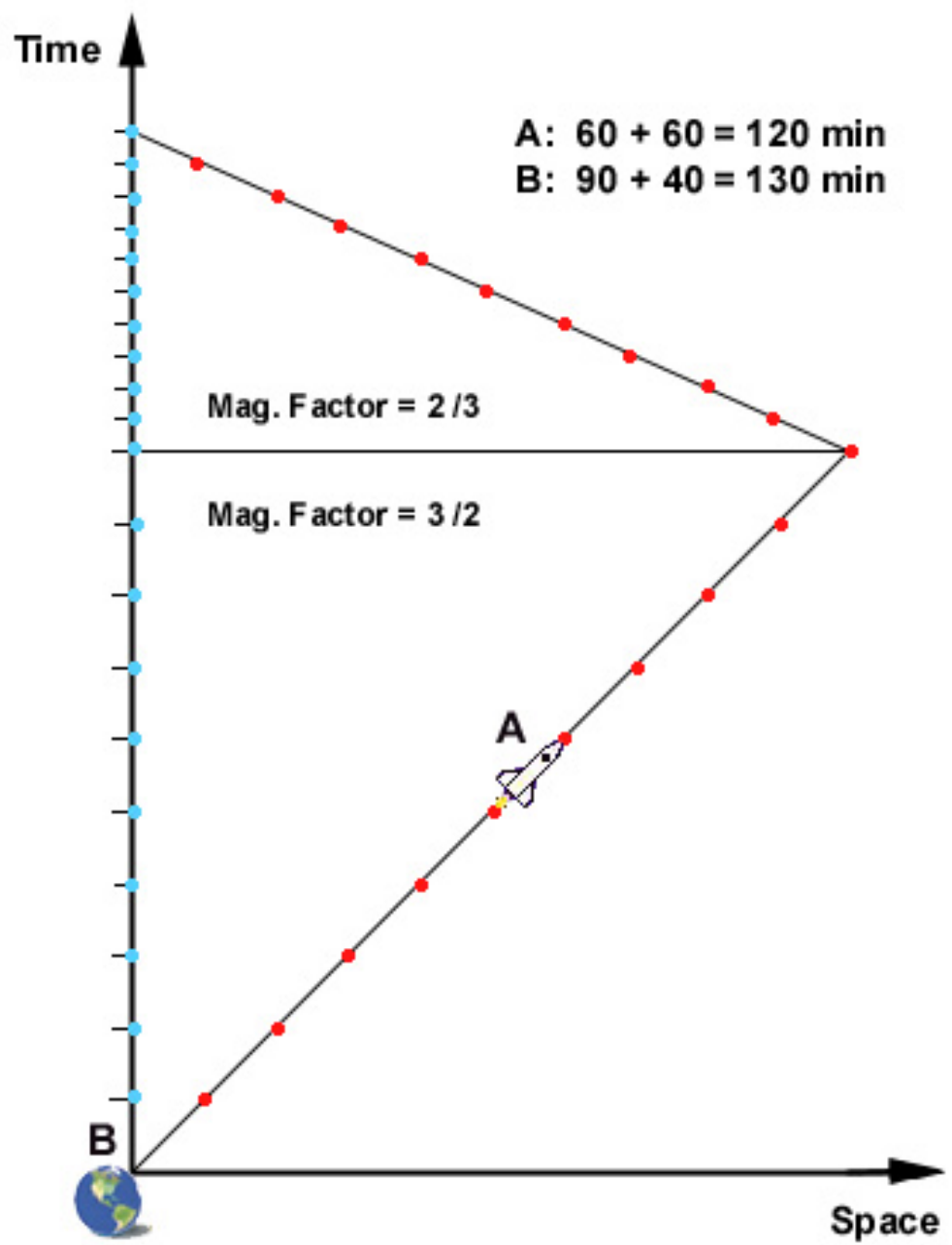














Can Two Universal Things be Independent of Each other

The feature that would distinguish one from the other –

Will Break/Violate UNIVERSALITY !

No two universal things can be independent of each other.

There must exist **UNIVERSAL RELATION** between them.



The Relation between Space and Time.

This can only be a

$$\text{VELOCITY} = \text{SPACE/TIME}$$

∴ A Universal Velocity is required to relate Space and Time and to bind them together

There must exist a **UNIVERSAL VELOCITY**
A Profound Conclusion, A Great Prediction

FROM A SIMPLE ARGUMENT

- a simple logic, no physics at all.



Universal Velocity

Some thing/particle should have a velocity which is the Same for All Observers/Frames irrespective of relative motion between Observers, i.e. Universal!

Is it possible in the Newtonian Mechanics?

- NO.

Because $w = u + v$

∴ No Velocity can be the same for All Frames.

If our "Crazy" logic is true,
We a need new mechanics!



“ c ”

Let ‘ c ’ denote the Universal Velocity,
the same for
ALL OBSERVERS / FRAMES

It is the **LIMITING VELOCITY** for **ALL
OBSERVERS**

What will **CHARACTERISE** such a thing
moving with c ?



“ c ”

**It cannot be at rest relative to ANY
OBSERVER**

as NO observer can travel with ‘c’

Since it CAN'T BE AT REST

Hence it CAN'T HAVE REST MASS !

IT HAS ZERO MASS



MOTION IS OF TWO KINDS

- (i) Particle can ...
 - have Non-Zero (rest) Mass
 - be held at Rest
 - be given Arbitrary Velocity
- (ii) Wave can
 - have No Mass
 - Never be at Rest
 - not have Arbitrary Velocity
 - Determined by the Medium



A Wave's velocity can be changed only by

Changing the medium

Moving the medium

Universal Medium:

Present Everywhere

Can't be changed/moved



A WAVE PROPAGATING IN IT WILL HAVE CONSTANT VELOCITY FOR ALL → **UNIVERSAL!**

Universal Velocity we are looking for can hence **ONLY** be provided by a

Wave propagating in a Universal Medium → *VACUUM*.

THERE MUST EXIST A WAVE PROPAGATING IN VACUUM WHICH WILL HAVE UNIVERSAL CONSTANT VELOCITY.

This is a profound prediction...



If Einstein were born in 1844 ...

- *If I were born in 1844 and thinking like this, I should be making such a profound prediction based on simple common sense argument in around 1870...*
- Right here we should have asked for a New Mechanics which keeps a Velocity Constant

That could have been Nothing but
SPECIAL RELATIVITY

- It could have preceded Maxwell Electrodynamics!



Preceding Maxwell

- In 1875 Maxwell (Synthesizing Coloumb / Ampere / Faraday / Displacement Current) gave the Electromagnetic Theory
- which precisely PROVIDED what one should have PREDICTED 5 years before him
- He would have simply JUSTIFIED/VERIFIED the Prediction and IDENTIFIED

Electromagnetic Wave / Light propagating in Vacuum

- This was later experimentally verified

by Hertz, and Michelson and Morley

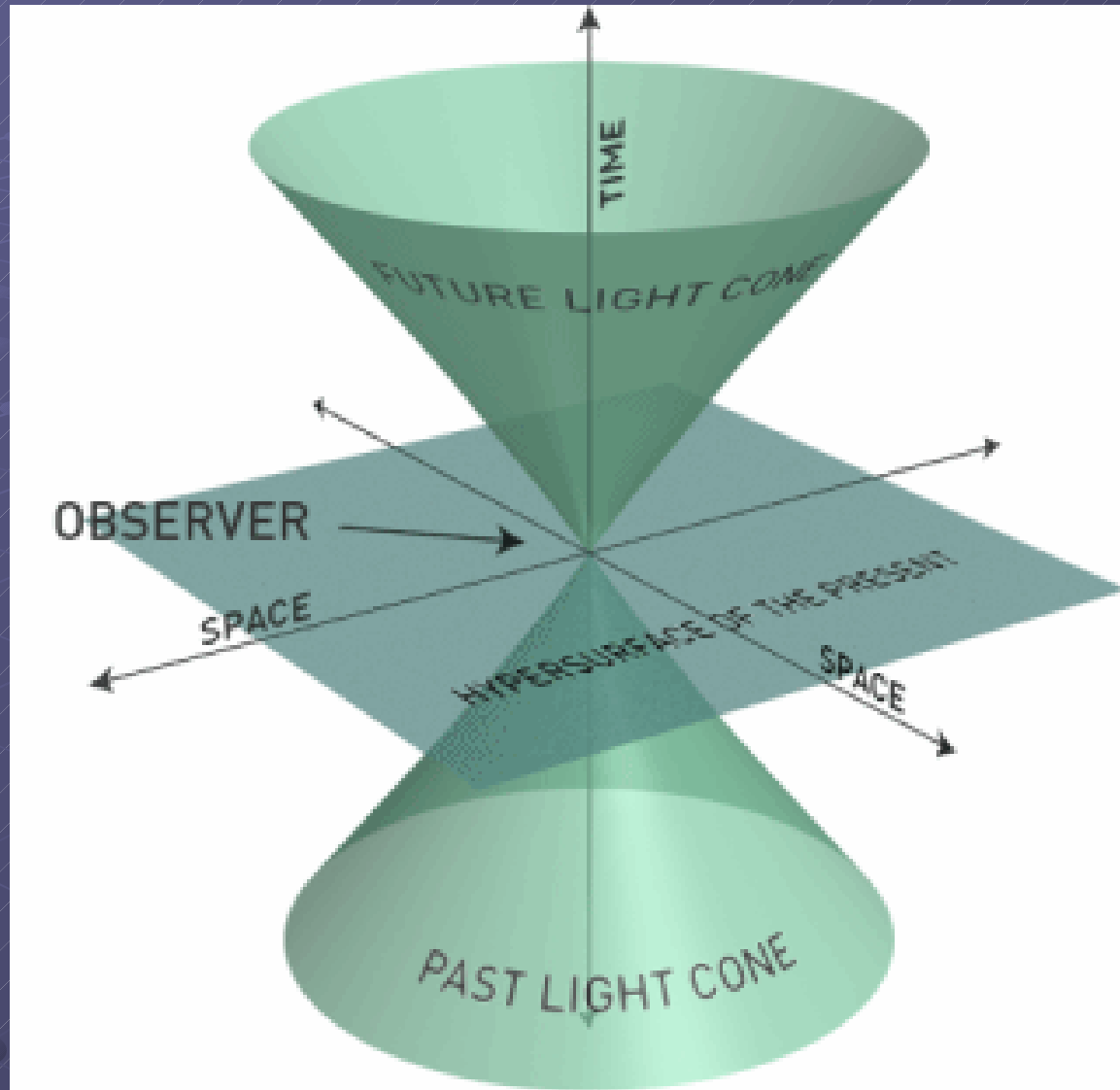
- It would have been a great verification of a profound



New Mechanics

The universalisation of mechanics valid for both *massive* and *massless* particles (eg: photons) that gave us new mechanics - Special Relativity which synthesised

- Space and time into Space-Time
- Mass - Energy - Momentum into a quadratic relation
- Light cone defining causal connection between events





Gravity

- The next natural question is

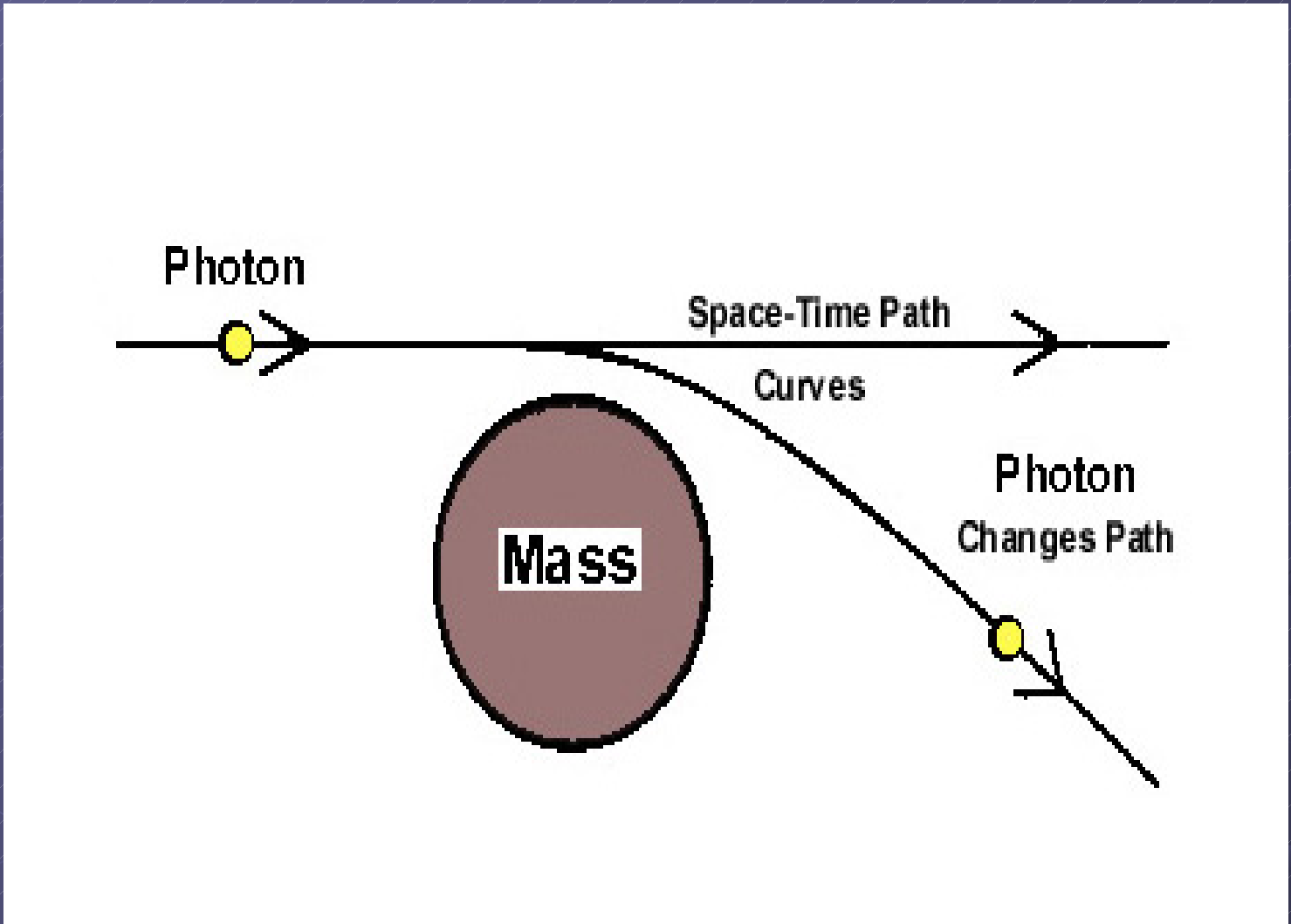
GRAVITY MUST AS WELL BE UNIVERSAL

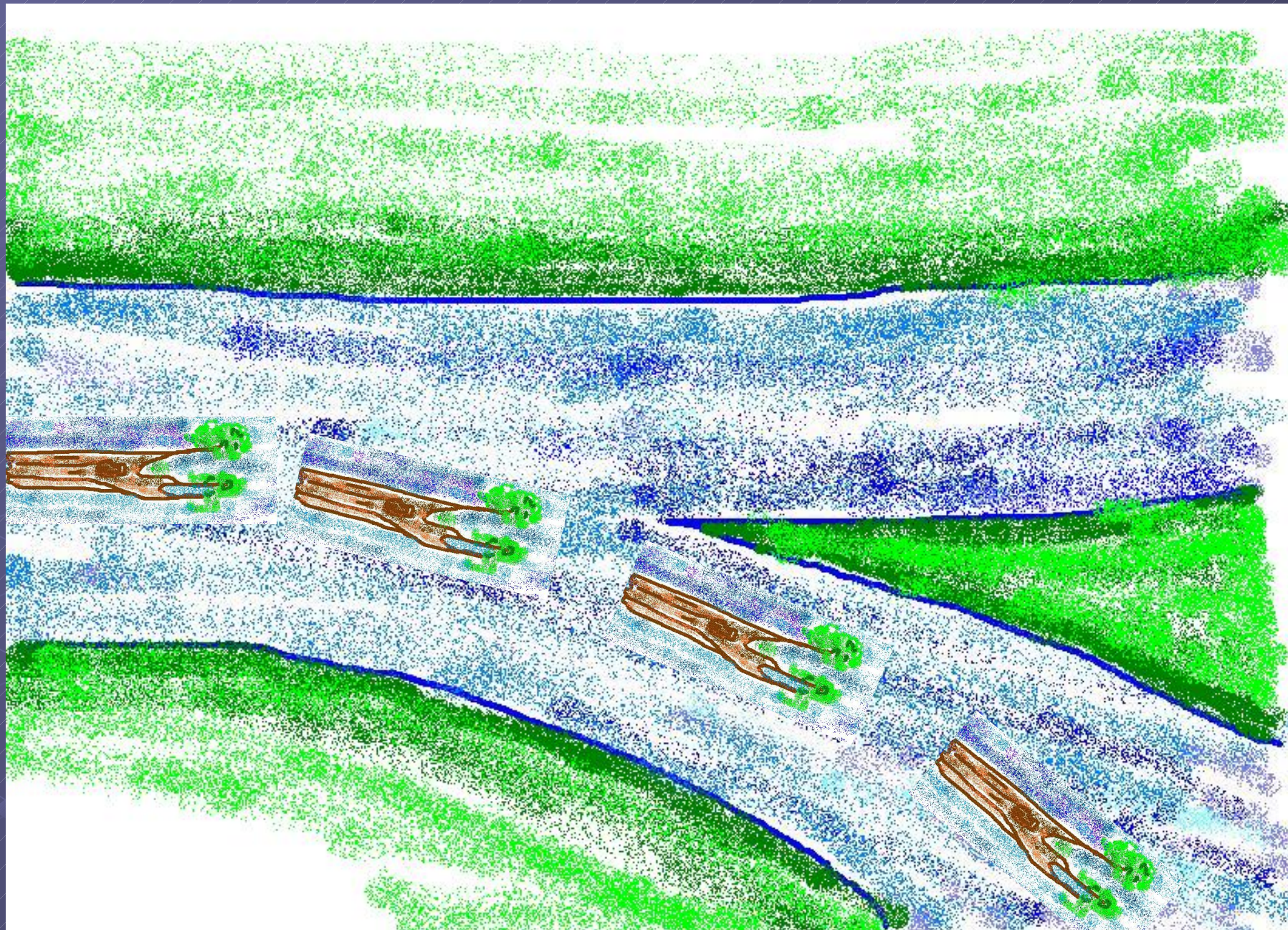
- Gravity must act on both massive as well as MASSLESS

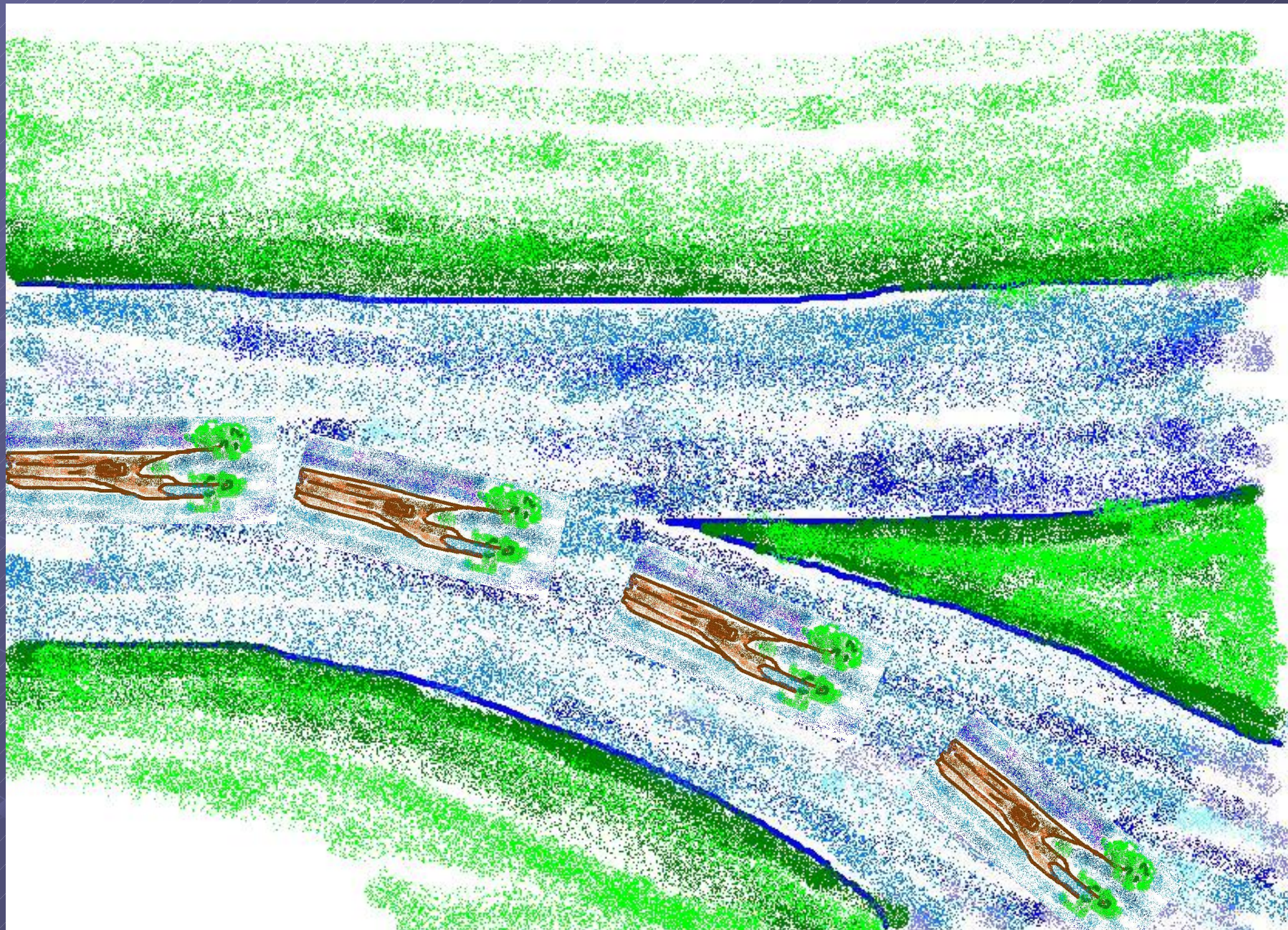
Problem: A Massless particle cannot change its velocity -
CONSTANT for ALL

YET IT MUST FEEL GRAVITY!

What is required is to make a massless particle feel
Gravity without changing its velocity?









Curving path of a Photon...!

The only way it could be done is by bending space (space-time) and letting particles (*massive* as well as *massless*) freely propagate in it

On geodesics of curved space-time

The solution ...

“Gravity can only be described by curvature of space-time”

**A New Theory of GRAVITATION !
GENERAL RELATIVITY**

The Greatest Feat of Human Thought!



Gravity revisited...

- Gravity is no more a force
- It has been completely synthesized into the geometry of space-time
- Law of gravity must follow from the curvature of space-time all by itself

It is the properties of Riemann curvature that lead to

EINSTEIN'S LAW OF GRAVITATION
which contains Newton's Law



Curvature Of 4-Dimensional Space-time Manifold

Riemann Curvature Tensor $\rightarrow R_{abcd}$

- It satisfies Bianchi Differential Identities

$$R_{ab(cd;e)} = 0$$

Analogue of Curl Grad = Div Curl = 0,

$;$ is a derivative relative to curved space-time

- Its contraction yields

$$G_{a^b ; b} = 0, \quad G_a^b = R_a^b - 1/2 R g_a^b$$

$$R_a^b = R_{ac}{}^{bc}, \quad R = R_a^a$$



The Einstein Equation of Gravitation

$$\mathbf{G}_a^b = \kappa \mathbf{T}_a^b + \Lambda \mathbf{g}_a^b, \quad \mathbf{T}^{ab}_{;b} = 0$$

\mathbf{G}_a^b is a second rank symmetric tensor
with Vanishing Divergence
A Second Order Differential Operator

on

the Metric Potential \mathbf{g}_{ab}

Λ is a new constant - to be determined by
experiment / observation



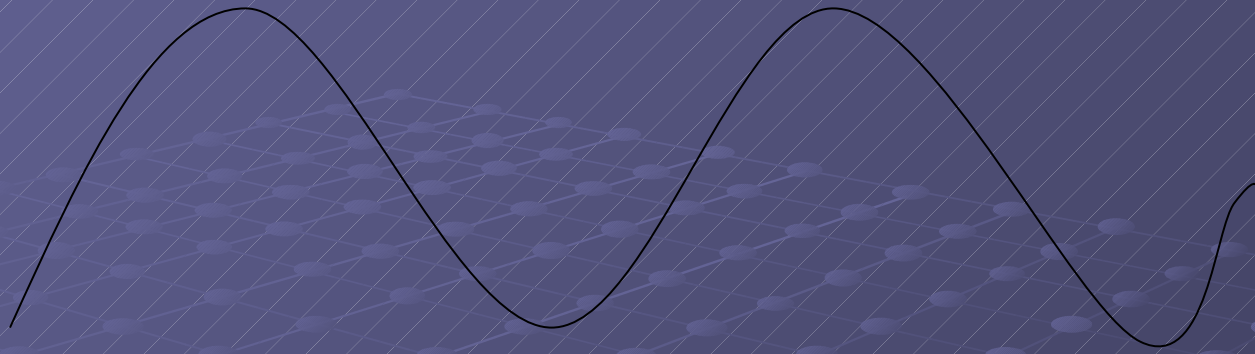
Seeing Beyond Einstein

Other great theory - **Quantum Mechanics**

At micro level - Matter consists of tiny pieces – quanta

Energetically : **Probe \approx Object**

The Process of observation disturbs object



4 – momentum : p^a

4 – wave vector : k^a

$$p^a = \hbar k^a$$

Basic Quantum Relation

In wave propagation uncertainty is inherent

$$\Delta x \Delta p \geq \hbar$$



Light wave propagates in vacuum

Wave propagation requires oscillation of micro structure - quanta

∴ Vacuum must have micro structure

It Can't be INERT

An ether ?

What is established ?



Vacuum

Vacuum can't provide a Reference Frame

Because it is everywhere

In the ocean also – No Reference unless there is a Flag Post

So why can't it have physical structure like an ocean ?

Like Matter, Space also has Micro-Structure

- **discrete and quantum**



Deep down even space can't retain

- Its continuum nature
- All tiny pieces / quanta

So What are these pieces ?

Basic Building Blocks of Space ... !

We don't know.



Quantum Space-Time

A New theory of Quantum Gravity !

Quantum Principle is universal

Hence it Must be related to Space-Time

Quantum Mechanics in Quantum Space – Time !

Unless that happens Quantum Theory is incomplete