

GEOMETRY of MAJORANA NEUTRINO

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ETTORE MAJORANA (05.08.1906 -)

was one of the last genius

of the romantic geometric period,

starting at the second half of the XIX century

and ending in the first half of the XX century

Poincare' DUALITY in Geometry : Homology and Cohomology Symmetries

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DUALITY in Physics:

- 1.The Space-Time structures**
- 2.The matter fermions**

TRIALITY in Physics :

- 1. The Space-Time structures**
- 2. The gauge internal symmetries**
- 3. The matter fermions**

TRIALITY

Poincare'/Lorentz symmetry

$SU(3) \times SU(2) \times U(1)$ gauge symmetry

Dirac and Majorana Fermion matter

What is the origin of $Q(\text{em})$ after Big Bang?

How did the Dirac and Majorana fermions appear after BB?

The Role of CPT?

1865. Maxwell equations: Theory of light

The Grand Unified Theory of Electricity, Magnetism and Light

Maxwell predicted the speed of light through the simple electrical experiments:

$$v^2 = \frac{1}{\mu_0 \epsilon_0} = 310,700,000 \text{ m/sec}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ (farad / m)}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ (henry / m)}$$

Faraday

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

Gauss

$$\vec{\nabla} \cdot \vec{E} = 0$$

$$\vec{\nabla} \times \vec{B} = \frac{1}{\mu_0 \epsilon_0} \frac{\partial \vec{E}}{\partial t}$$

$$\vec{\nabla} \cdot \vec{B} = 0$$

Ampere-Maxwell

Gauss

$$\vec{\nabla}^2 E = \frac{1}{\mu_0 \epsilon_0} \frac{\partial^2 E}{\partial t^2}$$

$$E = E_0 \sin\left(2\pi \frac{x - vt}{\lambda}\right)$$

$$v^2 = \frac{1}{\mu_0 \epsilon_0}$$

1676. Measuring the Speed of Light with Jupiter's moon Io

Ole Romer

Eclipse Io in two positions of the Earth



Diameter orbit of the Earth 22 min

$c=240\,000$ km/sec



Modern value of light velocity

1. c is not infinite !
2. c is constant ?
3. c is related with the properties of vacuua
4. $c_{\text{vac}}=299\,792\,458$ m/sec

What we know about vacuum now?
Can geometry help us ?

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Lorentz Group and Standard Model

Lorentz discovered the transformation which opened for us the Minkowsky geometry of our D=3+1 spacetime

- The invariance of the Maxwell equations
- The kinematical law of special relativity :

$$ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2$$

- The invariance of Dirac equations
- The principle of covariance in quantum field theory D=4
- SM
- GUT
- SUGRA
- Theory of strings/superstrings and D-branes

Theory of Electron and Dirac antiworld

1. The SU(2) theory of electron: spin $\frac{1}{2}$ D=3

$$\Psi = \begin{pmatrix} \alpha \\ \beta \end{pmatrix} \mapsto \text{spinor}$$

$$SO(3) \mapsto 2\pi$$

$$SU(2) \mapsto e^{i\pi}$$

$$SO(3) \mapsto 4\pi$$

$$SU(2) \mapsto e^{i2\pi}$$

2. Dirac equation

D=3+1

$$\Psi = \begin{pmatrix} \alpha \\ \beta \\ \gamma \\ \delta \end{pmatrix} \mapsto \text{bispinor}$$

$$SO(3,1) \mapsto SL(2, C)$$

In D=3+1 we have two families, particles and anti-particles.

In D=5+1 we can get additional two families and etc.

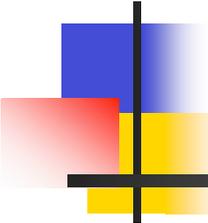
This is the property of D-dimensional Lorentz groups

Two problems:

1. to go to D>4!

2. N_f=3?

The ternary theory of neutrino

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1. The Lorentz properties of the Dirac particles in the D-4 Space-time: two generations-particles and anti-particles.
 2. The Lorentz binary properties of the Dirac fermions in the D-dim. space-time: 4,8,...generations.
 3. The Lorentz binary properties of Majorana neutrino in D-space.

1. The ternary theory of the fermions in D-space-time: spin $1/3$ (para-fermion)
2. Three generations due to ternary symmetries

Uncompleteness of the SM

1. The known Cartan-Lie symmetries, $SU(3) \times SU(2) \times U(1)$, of the SM did not explain us some (many) questions:

Confinement, families, fermion mass spectrum, mixing,

Neutrino problems, $N_f = N_c = D = 3, \dots ?!$

2. All known extensions of the SM based on the

Cartan-Lie symmetries/supersymmetries:

L-R, GUTs, SUSY, SUGRA, Strings/superstrings, ...

also did not bring us a success?!

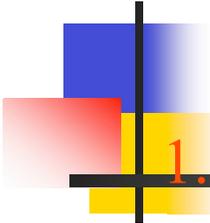
3. There were used two ways to overcome these problems:

a) High/superhigh energies;

b) New extra dimensions.

Majorana neutrino and extra dimensional world $D>4$

Experimental observation for Majorana fermion matter can give a new impetus to the understanding of the Lorentz symmetry and its extension into $D>4$

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1. The geometrical properties of the space-time Universe and its link with $SU(3) \times SU(2) \times U(1)$ symmetries of the SM;
 2. Matter-antimatter symmetry and baryo-genesis problem ;
 3. The proton-electron stability/non-stability;
 4. The geometrical nature of three Quark -Lepton families;
 5. The neutrino mass problem and the nature of oscillations;
 6. Dark symmetry of the SM and dark matter/energy in Cosmology.

High energies or Extra Dimensions?

1. The way to go to the high energies is "direct straight way" but it is limited by our energetic possibilities. Also, the idea of GUT and proton decay there is under big question?

2a. The first possibility on this way related with extra dimensions took the Kaluza-Klein ideas and used the COMPACTIFIED spaces having ADE- singularities. The importance to study these singularities was firstly discovered by F.Klein and then by Du-Val. This way has got the considerable progress in compactification of superstrings on Calabi-Yau spaces where we have got the indications on existing of new symmetries beyond Cartan-Lie (V,LSVV)

High energies or Extra Dimensions?

2b. The second possibility on this way related with LARGE extra dimensions and it is very difficult, since uses the new symmetries beyond Cartan-Lie/superstring symmetries (AV). But this way contains a lot of new and interesting discoveries....

Majorano-Diraco genesis

1. The existence of real Majorana particles (HM-exp) among the set of complex Dirac fermions in the SM could raise the question about mechanism of production of Dirac fermions through the Majorana fermion matter after Big Bang.
2. This mechanism may help explaining the origin of the Electromagnetic charge Q and $U(1)$ symmetry.
3. Such mechanism can be naturally related with baryogenesis and lead in an universal way for the proton-electron non-stability.

To construct such a mechanism one can start using the large Extra dimensions and embed there in new space-time and Internal symmetries which should be based on the Extension of ordinary Lie symmetries (Lorentz symmetry) And considering there in the bulk a new real fermion matter

Majorano-Diraco genesis

In this scheme all charge particles are confinement in our D=3+1 universe (brane cosmology $Q=0$ and $Q(p)+Q(e)=0$) and just Majorana neutrinos are messengers between our world and extra dimensional space-time

CPT – in variance \Leftrightarrow *Q_{em} – conservation*

$$e \mapsto ns$$

$$\Gamma = g_S^4 m_e^9 / M_S^8$$

$$M_S > \frac{g_2^{1/2}}{g_S^{1/2}} 10M_w = O(\text{TeV})$$

$$\delta v / c \rightarrow E^2 / M_S^2$$

$$\delta(v/c) \sim 10^{-4} - 10^{-5}$$

$$E \sim 20 \text{ GeV}$$

Majorana neutrino in D=6

The Dirac equation $\left(i\gamma^\mu \frac{\partial}{\partial x^\mu} - mc \right) \Psi = 0$

The Klein-Gordon equation $\frac{\partial_\mu^2}{\partial x_\mu^2} \Phi = 0$

The ternary generalization of Dirac /Klein-Gordon equations

D=3

$$\Psi = \begin{pmatrix} u \\ v \\ w \end{pmatrix}$$

Spinor triplet

$$(Q_1 \frac{\partial}{\partial x} + Q_2 \frac{\partial}{\partial y} + Q_3 \frac{\partial}{\partial z}) \Psi = 0 \rightarrow$$

$$\rightarrow \left(\frac{\partial^3}{\partial x^3} + \frac{\partial^3}{\partial y^3} + \frac{\partial^3}{\partial z^3} - 3 \frac{\partial^3}{\partial x \partial y \partial z} \right) u = 0$$

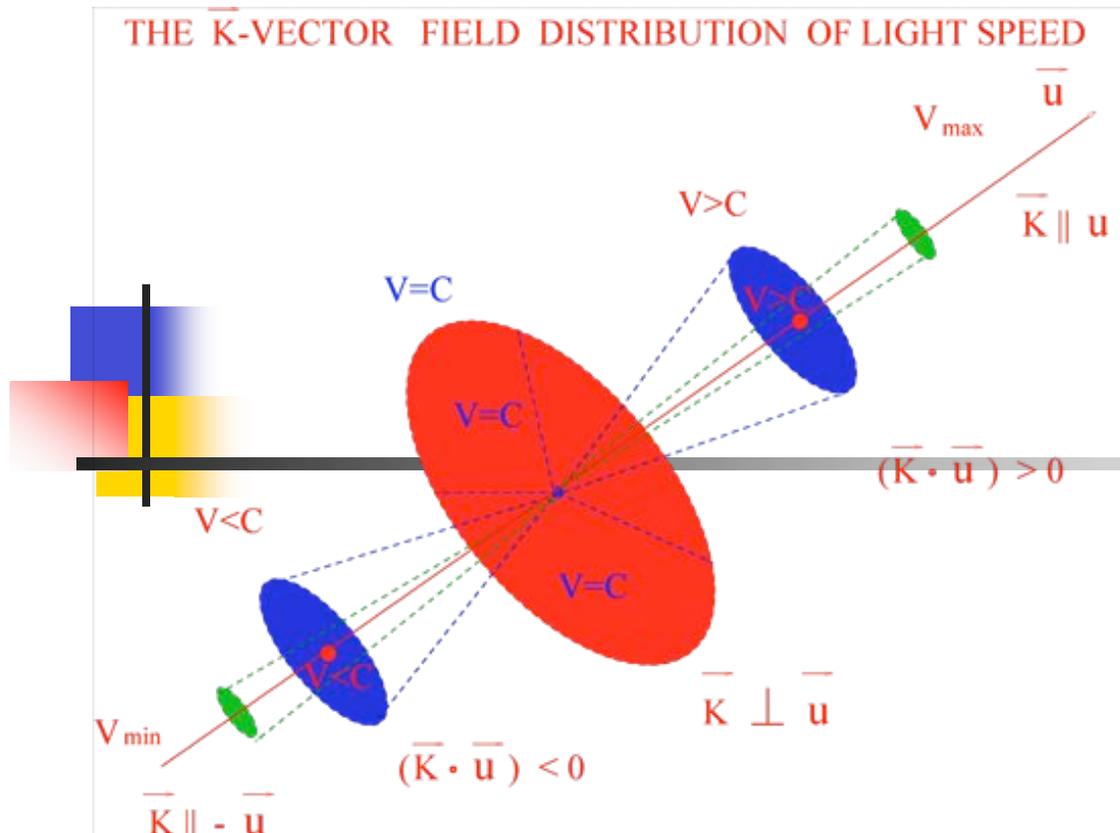
D=6

$$\Psi = \begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix}$$

Spinor 9-plet

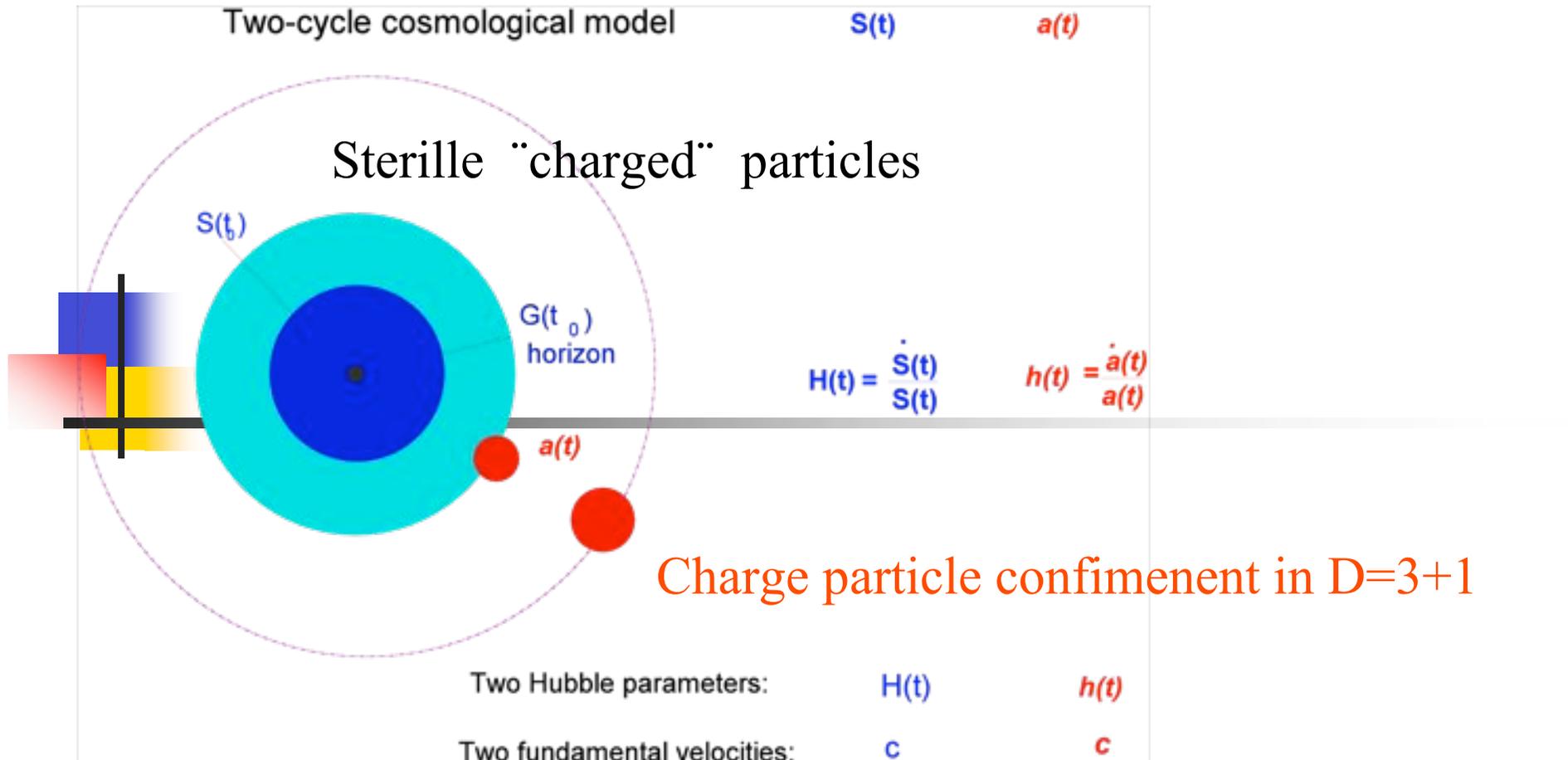
$$m_{\nu_e} = m_{\nu_\mu} = m_{\nu_\tau}$$

D=3+1 with $SO(2) \times SO(1,1)$ symmetry



1 rotation and 1 boost

Majorana neutrino in D=4+2



Charge particle confinement in D=3+1

$$c \gg c$$

Neutrino velocity measurements with OPERA



Long base=730 km
 $\Delta T = L/c = 2.4$ msec

L and ΔT from GPS
Expected as the best

$\sigma_t < 10$ nsec

$\sigma_L < 5$ cm ?

Then

$|\beta_\nu - 1| \sim \sigma_\beta \sim 4 * 10^{-6}$

CNGS – time of proton bunches
OPERA – time of ν event using
RPCs

Together with V. Ammosov

G. Volkov , Dark Matter Paris
2006

September 04, 2006

FNAL(1976-77) $\rightarrow 10^{-4}$

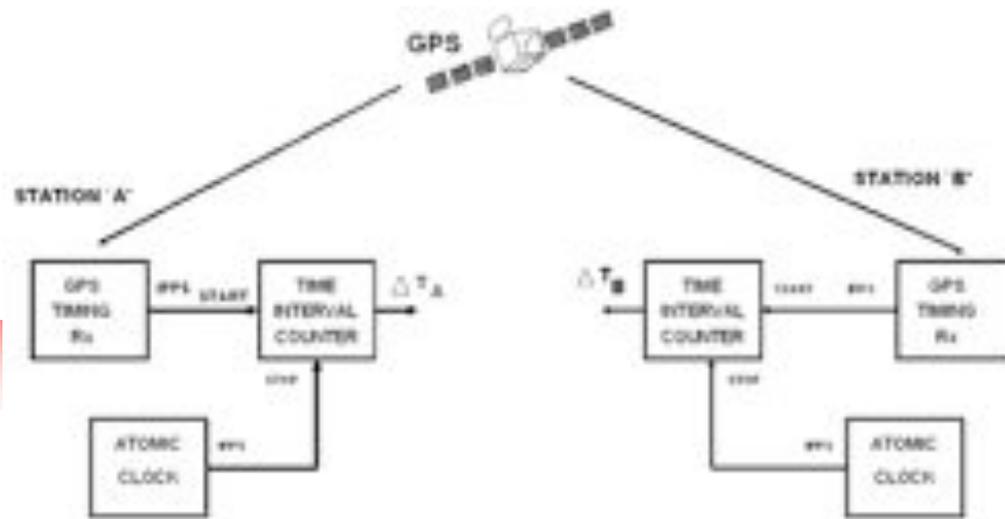
Neutrino velocity measurements with OPERA

Sources of errors:

- Time of bunches ~ 1 ns
- Time of event with RPCs \sim a few ns
- Distances within CERN – 5 cm
- Distances within Gran Sasso – 5 cm
- L CNGS-OPERA – 5 cm ?
- **Time synchronization ~ 10 ns (common view)**

- **together with V. Ammosov**

Neutrino velocity measurements with OPERA



TIME OFFSET OF ATOMIC CLOCK AT STATION 'A', WITH RESPECT TO ATOMIC CLOCK AT STATION 'B' = $(\Delta t_A - \Delta t_B) + \text{CORRECTION FOR OTHER SOURCES OF ERRORS TABULATED IN TABLE - 3}$

FIG.-1 GPS COMMON MODE COMMON VIEW TIME TRANSFER TECHNIQUE

$\Delta T = \Delta t_A - \Delta t_B$
 is mostly independent on systematics.
 Especially for small distances.

Atomic clocks for controls
 Rb – 10^{-10} accuracy
 Cs – 10^{-12}

Together with V.Ammosov

Neutrino velocity measurements with OPERA

Expected OPERA accuracy

Worse case : $\sigma_{\text{GPS}} > p$ bunch interspace (5ns now)

$\sigma_t \sim p \text{ batch length} / \sqrt{12} \sqrt{N}$ (now 2 batchs with 10.5 μs length)

At present $\sigma_t \sim 10 \mu\text{s} / \sqrt{12} \sqrt{1000} \sim 100\text{ns} \rightarrow \sigma_\beta \sim 4 \cdot 10^{-5}$

Is it possible to have 20 p batchs with 1 μs length ?

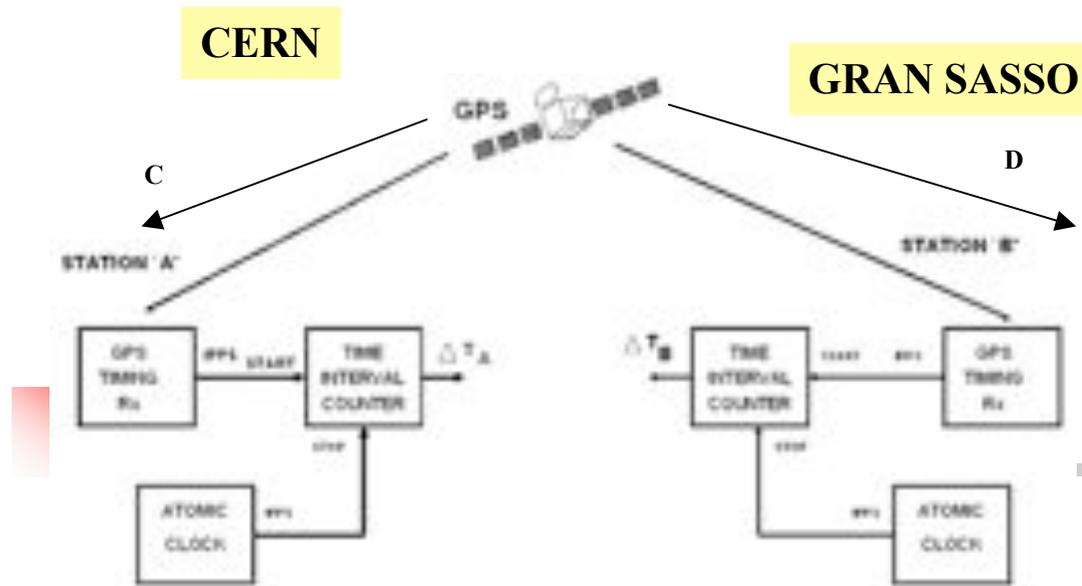
Better case : $\sigma_{\text{GPS}} < p$ bunch interspace (25ns as for LHC)

$\sigma_t \sim \sigma_{\text{GPS}} \sim 10 \text{ ns} \rightarrow \sigma_\beta \sim 4 \cdot 10^{-6}$

**First step – understanding of GPS accuracy
in common view technique**

Together with V.Ammosov

Neutrino velocity measurements with OPERA



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FIG.-1 GPS COMMON MODE COMMON VIEW TIME TRANSFER TECHNIQUE

Proposal

**Comparison of
A-C and B-D near time diff
with
A-B, C-D,... far time diff.
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World geometry and Photon, Electron, Majorana neutrino

1. New symmetries and extra dimensional world
2. Majorana-Diraco genesis
3. Proton/electron non-stability
4. The geometrical origin of $U(1)$

$$SO(3,1) \Leftrightarrow U(1)_{em}$$

5. Neutrino light $v > c$ at high energy
6. The geometrical nature of the SM: $SU(2) \times U(1)$? $SU(3)$?