



**Scientific dissertation  
by Dr. Enzo Bonacci  
on the possibility of a  
three-dimensional time  
in theoretical physics**





**Enzo Bonacci** was born in Brescia (Italy) in 1972 and spent there his childhood.

At the end of the 70's his family moved to Latina, city where he still lives and works; his school marks were so excellent to deserve the City Medal conferred by the Mayor.

During his scientific high school he received a prize that used to study in Cambridge (UK), where he was extremely impressed with Newton's manuscripts on maths and physics.

After graduating in Chemical Engineering from "La Sapienza" University of Rome, he spent his university prize to travel the world and to achieve diplomas in numerous foreign languages.

He was chosen to do his national service at the office of the Under Secretary of Defence. In spite of his scientific education he has never neglected his artistic side, writing poems and novels selected by international literary contests and becoming a columnist for some newspapers.

Member of the *ODI* (Italian Order of Engineers) since 2001, he has become technical-scientific consultant for important boards.

After qualifying in *mathematics* and *physics*, he has been teaching at Scientific High School since 2001, holding several posts like *Responsible for Public Relations* and *Secretary of the School Council*.

In 2003 he became responsible for the scientific project *Evolution of Rational Thinking and Epistemological Problems*.

During 2004 he became responsible for the IFTS project *Transformation of Agroindustrial Products*.

In January 2005 he was elected *Secretary of AEDE-Latina* (European Association of Teachers).

In 2007 he got the cover of BLU magazine about his effort to extend Relativity and he was elected Member of The Institute of Physics.

In 2008 he was selected among the 280 CBEL mathematicians and he was awarded with the Honorary Ph.D. in Theoretical Physics by the Cosmopolitan University.



# *Dissertatio De Tempore*



# *Could time be three-dimensional?*

*Mr. Enzo Bonacci (Italy), Honorary Doctor\**

## ***Abstract***

In order to rectify the lack of symmetry between time and space in Relativity an elegant hypothesis seems the 6D continuum. Beyond any aesthetical consideration and even accepting the mathematical consistency of some recent 3T theories, it is however necessary to supply a physical proof that time could effectively be tridimensional.

## ***Introduction***

Starting from two fundamental questions:

- 1) How many dimensions does a single temporal coordinate have?
- 2) How many temporal coordinates are necessary to define completely an event in the space-time continuum?

We find that each time coordinate seems to show a *bidimensional* nature, while the correct number of temporal coordinates necessary to define an event seems to be *three*.

In order to describe a so formulated SO(3,3) space-time the best representation in Euclidean conditions is given by three orthogonal axes (spatial directions) and three orthogonal surfaces (temporal orientations). Such 6D Cartesian reference frame, where the six coordinates are pairwise mutually perpendicular, becomes 6D Gaussian in a curved (but locally flat) space-time.

Being the space-time metric changed, all the equations in the ordinary 4D Relativity are subject to a six-dimensional revision.

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(\*) Ph.D. Honoris Causa in Theoretical Physics by Cosmopolitan University

# How should we represent time?

Let us analyze the space-time structure, the concept of event  $E(s,t)$  and the squared invariant interval  $\Delta\sigma^2 = \Delta s^2 - c^2\Delta t^2$ , without prejudices on time component.

In its simpler representation gravity is expressed by the vector acceleration  $\mathbf{g}$  whose dimensions ( $\text{m}\cdot\text{s}^{-2}$ ) show a link between a linear space and a squared time

Algebraic condition of reality for  $-c^2\Delta t^2$ : a negatively oriented *real* temporal surface  $\Delta S = -c^2\Delta t^2$  seems better than squaring the usual imaginary linear coordinate  $ic\Delta t$

In Einstein's triangle of velocities the measures of time  $\Delta t$  have in common an orientation (perpendicular to the moving direction) and not a direction

Differently from a linear space coordinate, each time coordinate is 2-dimensional  $\Delta t^2$ , requiring a surface to be measured namely the one perpendicular to motion

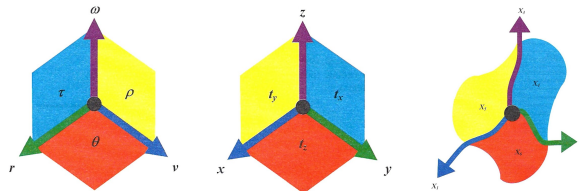
Permitting to permutate cause and effect in a well formulated proposition, the Reciprocity Principle applied to Lorentz equations leads to a 3D time

Algebraic symmetry  $\text{SO}(3,3)$ : since  $\Delta s^2 = \Delta x^2 + \Delta y^2 + \Delta z^2$ , then it should similarly be also  $\Delta t^2 = \Delta t_1^2 + \Delta t_2^2 + \Delta t_3^2$

Through an ideal diode-photodiode device in uniform circular motion ( $\mathbf{v} = \boldsymbol{\omega} \times \mathbf{r}$ ) time measures are different on each orientation  $\Delta\tau \perp \mathbf{v}$ ,  $\Delta\theta \perp \boldsymbol{\omega}$ ,  $\Delta\rho \perp \mathbf{r}$

The temporal coordinates necessary to define a single event in the space-time continuum are three, each one oriented perpendicularly to a space axis

6D reference frames:



Instantaneous

Cartesian

Gaussian

6D Lorentz equations:  $t_y' = t_y, t_z' = t_z$ .

6D squared invariant interval:

$$\Delta\sigma^2 = \Delta x^2 + \Delta y^2 + \Delta z^2 - c^2(\Delta t_x^2 + \Delta t_y^2 + \Delta t_z^2).$$

6D field equations:  $G_{\mu\nu} = kT_{\mu\nu}$ ;  $\mu, \nu = 1, \dots, 6$ .

# Each temporal coordinate is bidimensional

Differently from a linear space coordinate, each time coordinate is 2-dimensional  $\Delta t^2$ , requiring a surface to be measured (namely the one perpendicular to motion).

Such thesis is supported by a three-fold argumentation:

- 1) the dimensional analysis of the gravity vector  $\mathbf{g}$ , showing the link between a linear space and a squared time;
- 2) the algebraic reality of the invariant interval, leading to a negatively oriented temporal surface  $\Delta S = -c^2 \Delta t^2$ ;
- 3) the observation that in Einstein's triangle of velocities the measures of time  $\Delta t$  have in common an orientation.

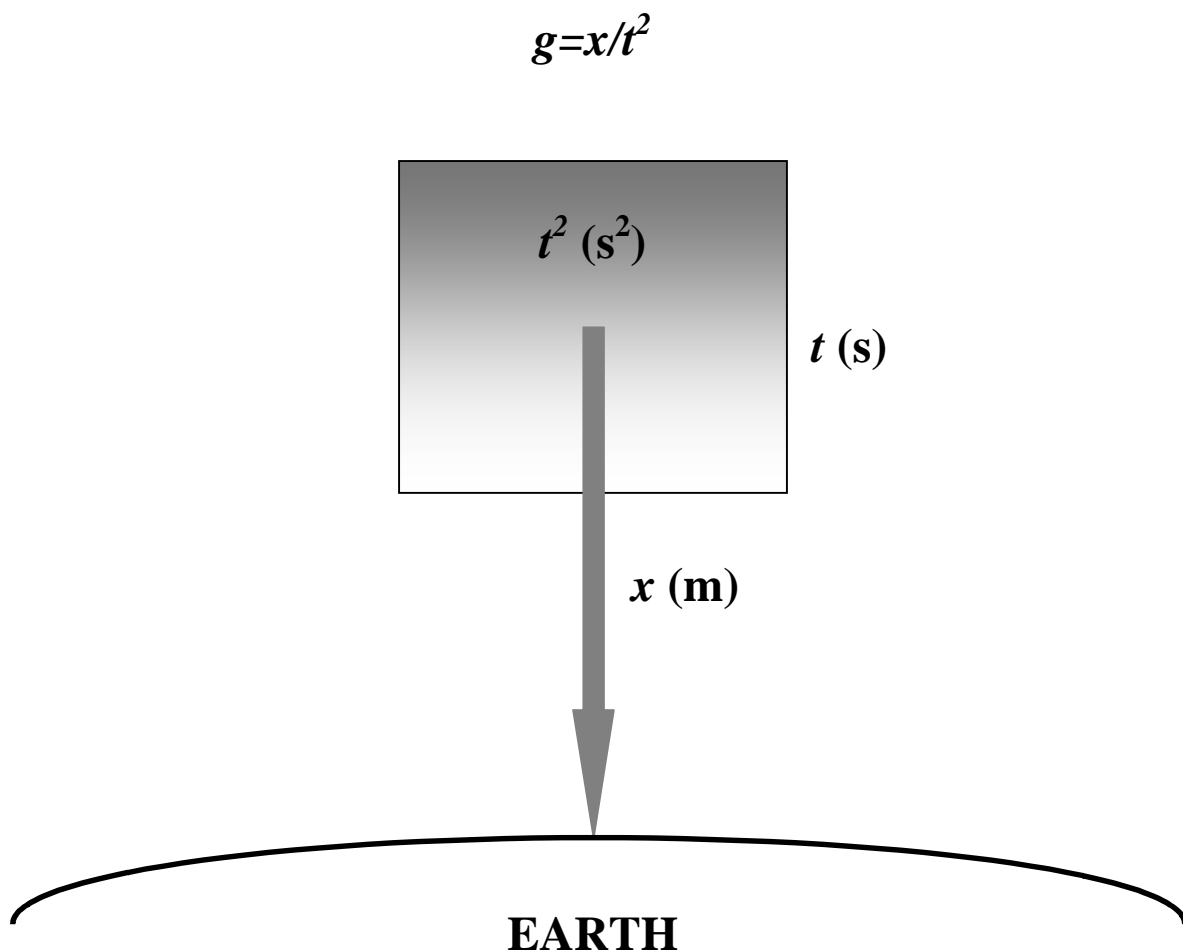
## ***Time as a surface from the dimensions of $\mathbf{g}$***

In any acceleration the linear space measure  $x$  is related to a squared time measure  $t^2$ .

Gravity in its vectorial formulation on Earth is the constant acceleration  $\mathbf{g}$  and according to my opinion it is more than a mere coincidence.

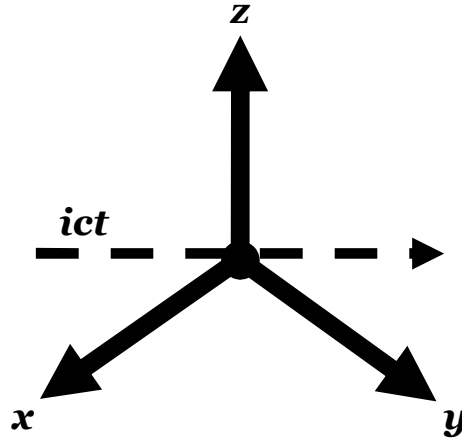
Since gravity is a direct expression of the space-time structure, the ratio between *linear meters* and *squared seconds* in  $\mathbf{g}$  could be a noticeable indication of the general connection between the spatial coordinate, to be treated as linear (*i.e.* described by an axis), and the temporal coordinate to be intended as squared (*i.e.* laying on a surface).

Let us represent the temporal surface as a square (whose side is the measured time  $t$ ) perpendicular to the displacement vector  $\mathbf{x}$  oriented towards the Earth as the gravity vector  $\mathbf{g}$ .

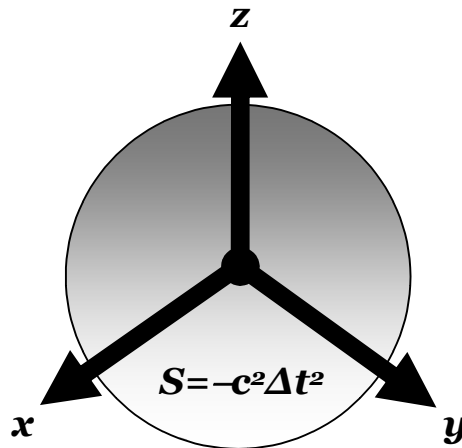


## ***Time as a surface from algebraic reality***

In  $\Delta\sigma^2$  the interpretation of the negative temporal term  $-c^2\Delta t^2$  from squaring the imaginary temporal coordinate  $ic\Delta t$  (with  $i = \sqrt{-1}$ ) presupposes an unjustified assumption of *dimensional homogeneity* between spatial and temporal coordinates, so that they are considered all linear.

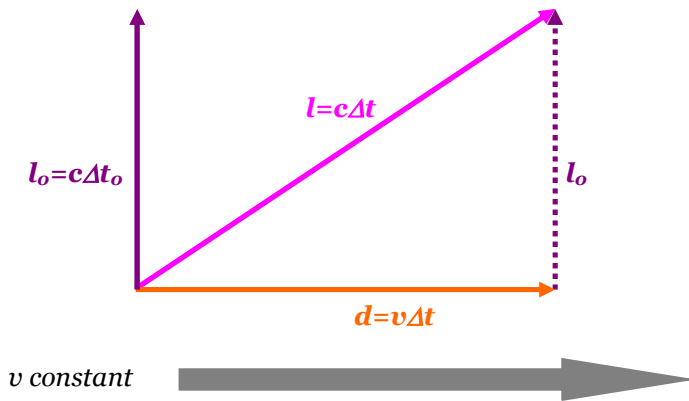


The condition of “algebraic reality” would lead to rather different conclusions: in order to be *real* a temporal coordinate should be a surface with a negative orientation  $\Delta S = -c^2\Delta t^2$ ; furthermore it should be a nonsense to think still about  $\Delta\sigma$ , being  $\Delta\sigma^2$  the minimal irreducible physical reality according to time measures on surfaces.



# Time as a surface from the triangle of velocities

The locally quasi-Euclidean space-time permits the Pythagorean theorem when composing the trajectories in the Uniform Rectilinear Motion:



$$l^2 = l_0^2 + d^2$$

$$(c\Delta t)^2 = (c\Delta t_0)^2 + (v\Delta t)^2$$

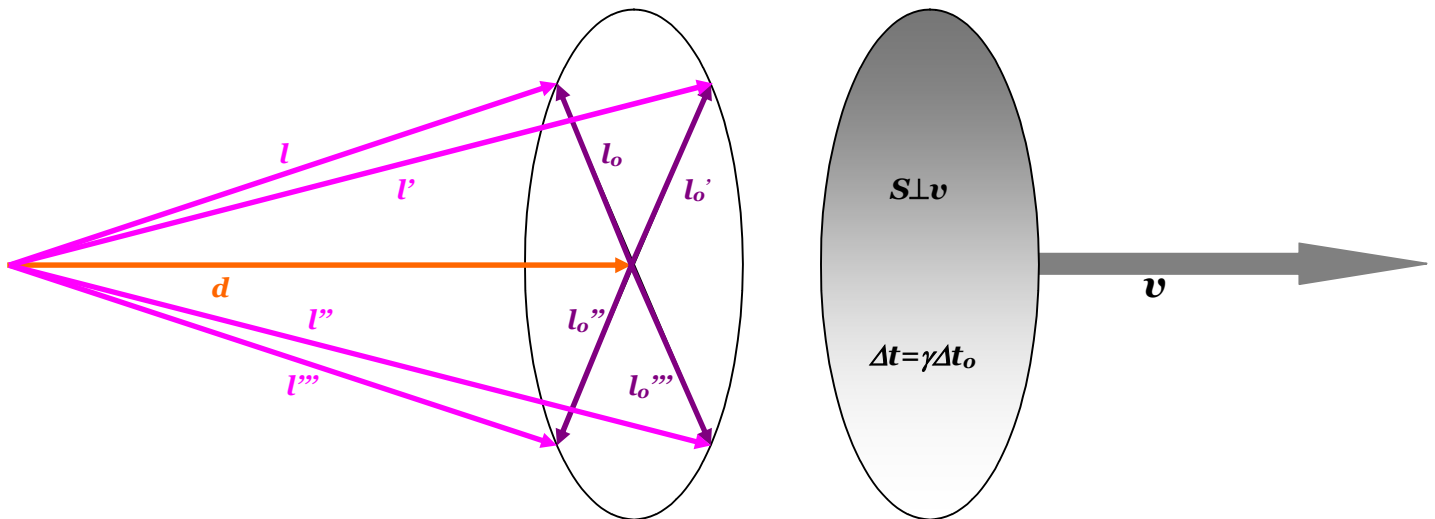
$$\Delta t^2 (c^2 - v^2) = c^2 \Delta t_0^2$$

$$\Delta t^2 (1 - \beta^2) = \Delta t_0^2$$

$$\Delta t^2 = \Delta t_0^2 / (1 - \beta^2)$$

$$\Delta t = \gamma \Delta t_0$$

The measure of time does not depend on the specific direction of  $\mathbf{l}_0$  but upon its *orientation*, always perpendicular to the vector velocity  $\mathbf{v}$ ; what the same measures of  $\Delta t$  have in common is a *surface*:



# An event requires three time coordinates

The temporal coordinates necessary to define a single event in the space-time continuum are three, each one locally oriented perpendicularly to a space axis.

Such thesis is supported by a three-fold argumentation:

- the Reciprocity Principle applied to Lorentz transformations, leading to a three-dimensionally oriented time;
- the algebraic symmetry between space and time, opening to the SO(3,3) model;
- the measure of time by an ideal diode-photodiode device in uniform circular motion, revealing the 3T.

## **3D time from the Reciprocity Principle**

If cause and effect are not inescapable in the physical description then *action and reaction* can be considered *equivalent* and Newton's third law of motion should be reformulated as *reciprocity*.

The reciprocity principle in physical description expresses the invariance following the substitution between subject (cause) and direct object (effect) within a well-formulated proposition.

Overcoming the scheme cause/effect for the benefit of a perfect logic symmetry and temporal reversibility, it seems the missing link to unite Relativity and Quantum Mechanics with respect to the *acausal* and *precausal* paradoxes.

In a Euclidean space-time (flat) the Fitzgerald contraction must be interpretable both in the conventional direction:  $0 < v < c \Rightarrow \Delta x < \Delta x_0$  (the speed of the body generates the length's contraction in the movement direction), and in the reversal:

$\Delta x < \Delta x_0 \Rightarrow 0 < v < c$  (the length's contraction in a certain direction generates the speed of the body).

Similarly, based on reciprocity and time's three-dimensionality, in a Euclidean space-time (flat) the time dilation can be read both in the conventional direction:

$0 < v < c \Rightarrow \Delta t > \Delta t_0$  (the speed of the body generates the time dilation in the movement direction),

and in the reversal:

$\Delta t > \Delta t_0 \Rightarrow 0 < v < c$  (the time dilation in a certain direction generates the speed of the body).

If time were not three-dimensional, the second interpretation would not be possible; in fact, without a direction identifying  $\Delta t$ , a temporal dilation could not be associated with a specific vector velocity  $\mathbf{v}$ .

## **3D time from algebraic symmetry**

Since in  $\Delta\sigma^2 = \Delta s^2 - c^2\Delta t^2$  the spatial term is

$$\Delta s^2 = \Delta x^2 + \Delta y^2 + \Delta z^2$$

then the temporal component should be

$$\Delta t^2 = \Delta t_1^2 + \Delta t_2^2 + \Delta t_3^2$$

by algebraic symmetry.

Such aesthetical consideration induced many researchers to explore the orthogonal without reflections group SO(3,3) with different approaches.

## **Overcoming three fundamental objections**

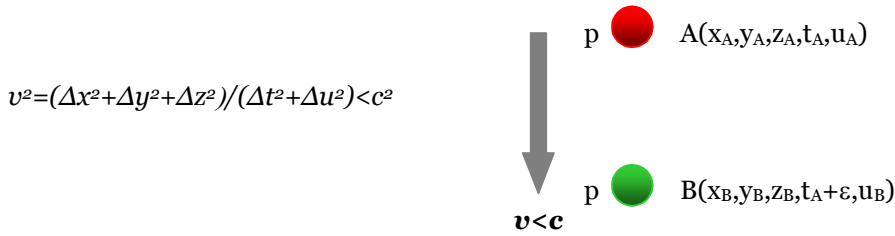
There are three serious objections, evidenced in particular by Strnad, against the multidimensional time hypothesis:

- 1) there would be tachyons observed in four dimensions;
- 2) there would be closed time like loops which violate causality;
- 3) the sign of the Maxwell action would be incorrect.

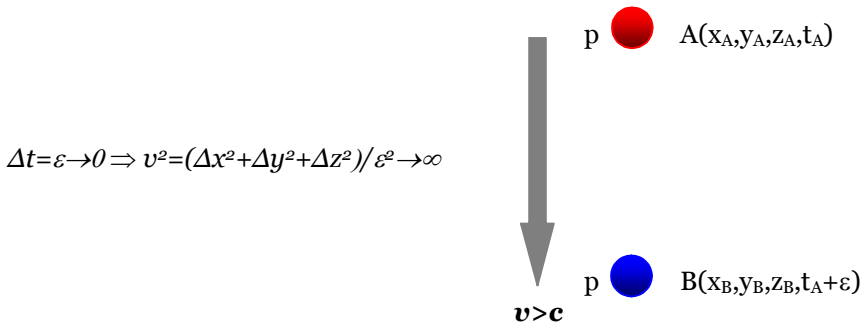
The works of many researchers, *e.g.* Ziino, confuted each of them, showing how the apparent paradoxes come all from the fact that if the real world has multiple dimensional time, then the picture of the world which we measure by a monodimensional clock would be a distorted one.

## Beyond the speed of light?

In a  $(4+n)$ D space-time (with at least one time extra-dimension  $u$ ) the normal motion at  $v < c$  along the temporal dimensions  $u$  and  $t$  (with an infinitesimal variation  $\Delta t = \varepsilon$ ):

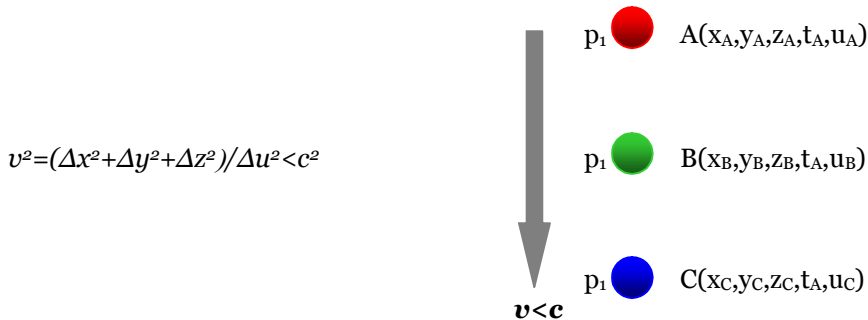


would appear faster than light in the usual 4D space-time (if the time extra-dimension  $u$  was somehow hidden):

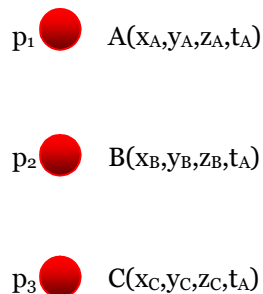


## Multilocation of a particle?

In a  $(4+n)$ D space-time (with at least one time extra-dimension  $u$ ) the normal motion at  $v < c$  along the temporal dimension  $u$  (keeping  $t$  invariant):



would be interpreted as appearance of a particle in many places at the same time  $t$  in the usual 4D space-time (if the time extra-dimension  $u$  was somehow hidden):



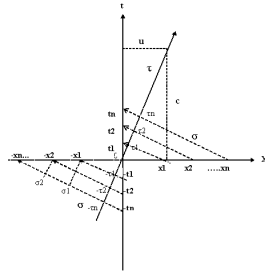
## *The four pioneers of the model SO(3,3)*

	<b>Why should time have three dimensions?</b>	<b>Which representation?</b>	<b>Why does time seem scalar?</b>	<b>The nature of the two extra-dimensions ?</b>	<b>Affinity with the String Theory?</b>	<b>Why are there acausal phenomena?</b>
<b>XIADONG CHEN (USA)</b>	The temporal extra-dimensions explain the not-local motion; they must be 2 for an actual physical observation	Motion equations with multiple proper time; the trajectory given by 3 world lines corresponds to the wave function	The time extra-dimensions are hidden, with radius minor than Planck length	Although temporal the two extra-dimensions show up space-like in 4D (negative sign)	Lagrangian similar to the bosonic strings; compact and periodical extra-dimensions	Due to the "invisible" motion lines along the two temporal extra-dimensions
<b>DANNY ROSS LUNSFORD (USA)</b>	Six dimensions are the minimum number leading to a variational principle devoid of arbitrary factors	6D Weyl geometry with a symmetrically connected space	Not specified	The two extra-dimensions are coordinatized matter	Not related	Not specified
<b>GEORGE A.J. SPARLING (USA)</b>	The rotational symmetry of the not local spinorial transform $\Xi$ with two 6D twistor spaces forces the space-time to be 6D	Three six-dimensional spaces (the ordinary space-time and two twistors) united by Cartan triality. The triality symmetry of the type developed by Elie Cartan, associated with the real Lie group $O(4, 4)$ , requires a 6D space-time of signature (3,3)	The space 3d and time 3d; from which $s^2 = x^2 + y^2 + z^2 - t^2 - u^2 - v^2$ , (with $u$ and $v$ time extra-variables) are around the ordinary 4D space-time	The 2 extra-dimensions have negative sign (are timelike) because the geometry of twistor spaces is ultrahyperbolic	The trouser-pants diagram becomes an amplitude relating 3 strings, one in each of 3 <i>different</i> spaces (1 extended space-time + 2 twistor spaces)	Not specified
<b>ENZO BONACCI (ITALY)</b>	Direct measurement diode-photodiode in UCM. Principle of Reciprocity applied to Special Relativity	Riemannian classic, with a 6D Gaussian reference frame: three spatial axis and three temporal surfaces	Bodies' structural complexity privileges the tangential time (with rare exceptions)	Same nature, same rank and same sign of Relativistic proper time	6D Gaussian reference with three temporal surfaces; matter as electromagnetic helix	By Absolute Relativity there is indistinguishability among atemporal systems at $v=c$ and acausal at $v < c$

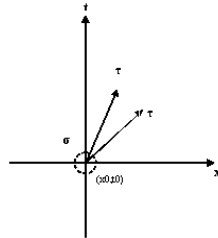
# The quantum approach by Chen

Basic quantum principles of single particle (non-localization, non-determinism, spin and related statistics) are derivable from pure geometry of two extra time dimensions and the consequent 6-dimensional KK theory could unify electromagnetism and gravity. Xiaodong Chen uses the two dimensional world sheet starting the calculation from the same lagrangian of bosonic string, but instead of considering the extra dimension  $\sigma$  as string, he interprets it as world line of extra dimensional time. He proves that only one extra time dimension  $\sigma$  leads to complex space-time values, while two extra time dimensions  $\sigma$  and  $\phi$  give the correct possibility of physical observable in measurement (under the hypothesis they are both compact small loop satisfying  $2\pi$ -period condition and whose radius has scale of Planck length). A puntiform particle moves along three separate world lines, each one associated with one proper time; and the whole trajectory of particle becomes a wave in space. The projections of extra two world lines in 4-dimensional spacetime are space like because of their signs, but in the whole 6-dimensional spacetime, all three world lines are light like. Electron can be expressed as time monopole. Chen introduces the 5<sup>th</sup> component of momentum-energy tensor for general electromagnetic field, which can also help us to get spin magnetic moment but cannot include strong and weak forces because these interactions are related to nucleons which have finite spatial size.

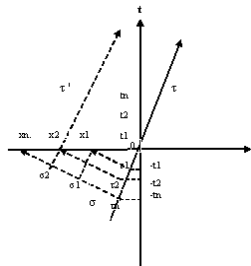
World line  $\tau$  and world line  $\sigma$  on  $t-x_i$  plane in Minkowski space. Particle can move along both world lines, slope of  $\tau$  is  $u/c$ . At  $t=0$ , the single particle will be shown at all positions:  $-x_1, -x_2, \dots -x_n$  with different values of  $\tau$  and  $\sigma (-\tau_1, \sigma_1) \dots (-\tau_n, \sigma_n)$ . Also the single particle will be shown at  $x=0$  at different time:  $t_1, t_2, \dots t_n$  with different  $\tau$  and  $\sigma$  values; where  $x_n = h/mu$  and  $t_n = h/mc^2$  which are De Broglie wavelength and period:



World lines  $\sigma$  is a infinitesimal loop to fixed point  $(x_0, t_0)$ .  $\tau$  perpendicular to loop  $\sigma$ , so  $\tau$  can point to any direction, the slope of  $\tau$  is from  $-\infty$  to  $\infty$  which means the momentum is from  $-\infty$  to  $\infty$ :



Current universal time is  $t=-t_2$ , particle reaches  $x_2$  at  $t=0$ , it is in future since  $t=0 > -t_2$ . When event 2 happens at  $x_2$ , the particle interacts with other particles, so particle's world lines is changed, its next movement will be based on new world line  $\tau'$ :



# *The field equations by Lunsford*

Danny Ross Lunsford thinks that Weyl's theory in 4D failed because lacking of a proper variational integrand. He finds that first in 6D we obtain a variational principle with no arbitrary factors:

$$\int \mathbf{R}\mathbf{W}\sqrt{d^6\omega} = \int \mathbf{R}\mathbf{W}d\Omega = \mathbf{o}, \text{ where } \mathbf{W} = \mathbf{F}^{mn}\mathbf{F}_{mn}.$$

He develops a Weyl geometry over  $SO(3,3)$  as base, under which gravity and electromagnetism are essentially unified via an irreducible 6-calibration invariant Lagrange density and corresponding variational principle.

The extra dimensions are given a physical meaning as "coordinatized matter".

Matter appears by interpreting source-free homogeneous fields over a 6-dimensional space of signature (3,3) as interacting inhomogeneous fields in spacetime.

The inhomogeneous energy-momentum relations for the interacting fields in spacetime are automatically generated by the simple homogeneous relations in 6D.

The Einstein-Maxwell equations are shown to represent a low-order approximation, and the cosmological constant must vanish in order that this limit exists.

The conformal covariant derivative of a tensor of weight  $N$  is  $D_\alpha$ :

$$\mathbf{D}_\alpha \mathbf{T}_{(N)} = (\nabla_\alpha + N\mathbf{A}_\alpha)\mathbf{T}_{(N)}.$$

It's a formalism necessary to a joint field theory for the electromagnetism  $A$  and the gravitation  $g$ .

Lunsford's combined electromagnetic and gravitational equations are:

$$\left\{ \begin{array}{l} \mathbf{R}_{\underline{mn}} = (\mathbf{2R}/\mathbf{W})\mathbf{T}_{mn} - (\mathbf{1}/\mathbf{2W})(\mathbf{D}_m\mathbf{D}_n + \mathbf{D}_n\mathbf{D}_m)\mathbf{W} \\ \frac{\mathbf{1}}{\sqrt{\mathbf{W}}} \partial_n (\sqrt{\mathbf{R}}\mathbf{F}^{mn}) = \frac{\mathbf{5}}{\mathbf{4}} \mathbf{D}^m\mathbf{W} \end{array} \right.$$

Since  $T$  has conformal weight  $-1$ , the equations are calibration invariant.

The underbars on the indices of the Ricci tensor indicate the symmetric part.

When do these equations take on the form of Einstein's equations?

Before we must introduce the conformal wave equation for  $W$ (=weight):

$$\mathbf{D}_m\mathbf{D}^m\mathbf{W} = \mathbf{o} \quad (\text{conservation of "geometrical charge" invariantly written}).$$

Then we may write:

$$\mathbf{R}_{\underline{mn}} - \mathbf{1}/\mathbf{2}\mathbf{g}_{mn}(\mathbf{R}-\Lambda) = (\mathbf{2R}/\mathbf{W})(\mathbf{T}_{mn} - \mathbf{1}/\mathbf{4}\mathbf{g}_{mn}(\mathbf{W}/\mathbf{R})(\mathbf{R}-\Lambda) - (\mathbf{1}/\mathbf{4R})(\mathbf{D}_m\mathbf{D}_n + \mathbf{D}_n\mathbf{D}_m)\mathbf{W}).$$

The last two terms on the right must cancel:

$$((\mathbf{D}_m\mathbf{D}_n + \mathbf{D}_n\mathbf{D}_m + \mathbf{g}_{mn}(\mathbf{R}-\Lambda))\mathbf{W}) = \mathbf{o}.$$

Contracting with the metric and by the conformal wave equation for  $W$ :

$$(\mathbf{R}-\Lambda)\mathbf{W} = \mathbf{o}.$$

Thus we obtain general relativity only in the limit:

$$\Lambda = \mathbf{o}, \mathbf{R} \rightarrow \mathbf{o}, \mathbf{W} \rightarrow \mathbf{o}, \mathbf{R}/\mathbf{W} \rightarrow -\mathbf{4}\pi\mathbf{G}.$$

If  $R$  and  $W$  differ from zero by a factor of first order, their product is second order and may be ignored; so the Einstein-Maxwell equations are to be regarded as first-order approximation to the full calibration-invariant system.

## The spinorial interpretation by Sparling

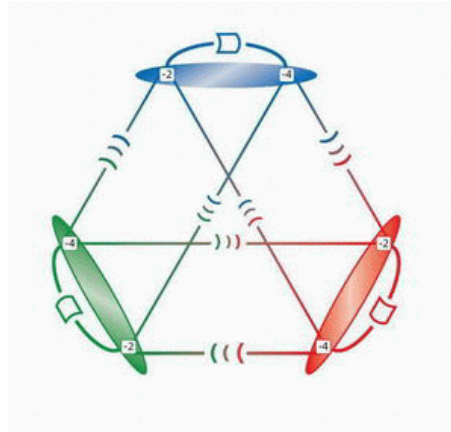
George Sparling's work has three six-dimensional spaces which at one level are on an equal footing and which are bound together by a new integral transformation, which he calls the  $\Xi$ -transform.

Two of these spaces can be understood at the space-time level as twistors. Then the third space can be given a space-time interpretation, but only if we have two extra dimensions: so it is the requirement of symmetry between the spinor spaces and the space-time that dictates that the extra dimensions be there.

In Sparling's theory, the two twistor spaces are each six-dimensional, forcing space-time to also have six dimensions, in accordance with Cartan's unifying triality. Because the twistor spaces' geometry is ultra-hyperbolic, the extra dimensions are time-like (minus sign).

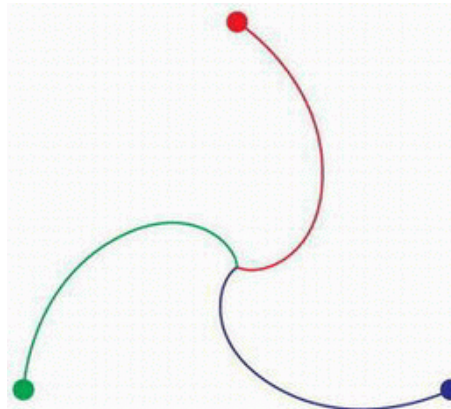
The four dimensional space is hyperbolic as usual, but in the surrounding space there are equal numbers (3 each) of space and time dimensions, so the formula for  $s^2$  reads something like  $s^2=x^2+y^2+z^2-t^2-u^2-v^2$ , where  $u$  and  $v$  represent the new time variables.

The structure is a Xi-transform, which moves between the three spaces in the directions given by the bendings of the upper case Greek letter Xi. The distorted squares represent the wave operator. The product of a wave operator and a Xi transform, taken in any order, is zero:



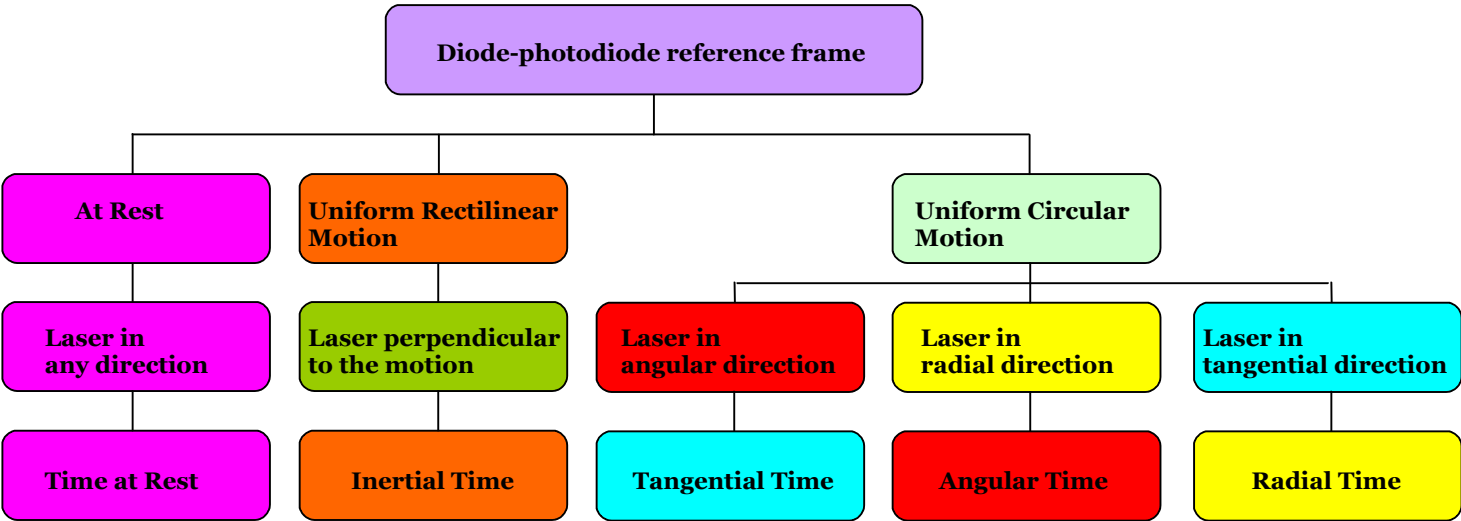
*The analytical structure underlying the spinorial theory. Image credit: Erin Sparling.*

Sparling's spinorial theory is based on Einstein's general relativity and Elie Cartan's triality concept, which can link space-time with two twistor spaces. Twistor spaces are mathematical spaces used to understand geometrical objects in space-time landscapes:



*Cartan's triality symbol links two twistor space and space-time. Image credit: Erin Sparling*

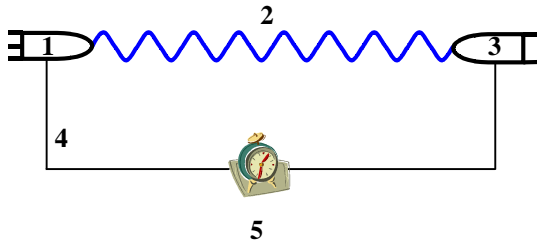
# 3D time from diode-photodiode measure



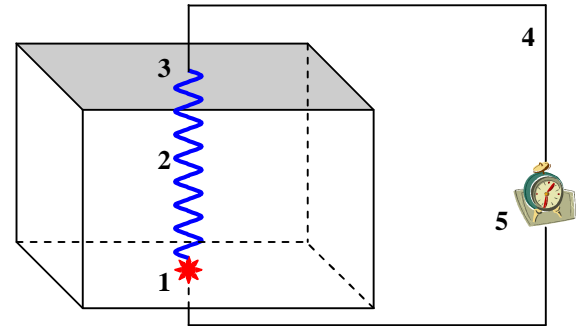
# Diode-photodiode measurement in UCM

## Diode-photodiode measurement system.

Time is measured on an orientation, *i.e.* between two parallel planes diode-photodiode:



Let the diode be puntiform while the photodiode is distributed on the opposite wall:



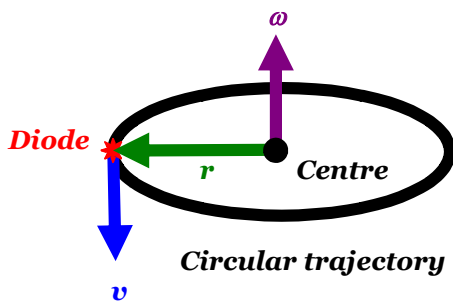
### Caption:

- 1) Diode
- 2) Laser ray
- 3) Photodiode
- 4) Feedback
- 5) Chronometer

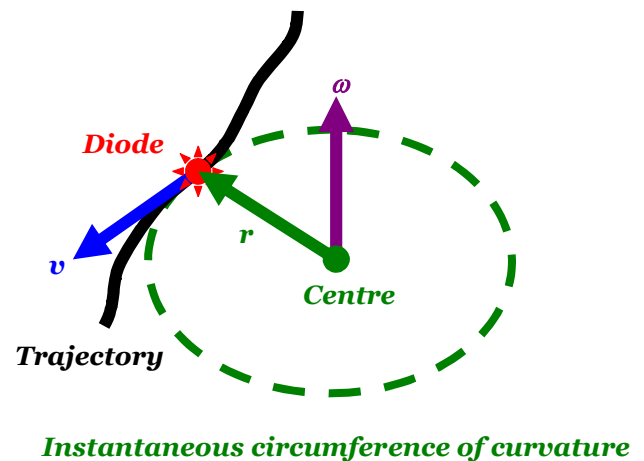
## Why the Uniform Circular Motion?

- Each point of a continuous trajectory is assimilable to an instantaneous UCM.
- In fact, each point individuates the three instantaneous vectors:
  - $\mathbf{v}$ =tangential velocity;
  - $\mathbf{r}$ =radius of curvature;
  - $\boldsymbol{\omega}$ =angular velocity.
- The rectilinear trajectory is a limit case of degenerated UCM:  $r \rightarrow \infty$ ,  $\omega = 0$ .

In the Uniform Circular Motion:  $\mathbf{v} = \boldsymbol{\omega} \times \mathbf{r}$



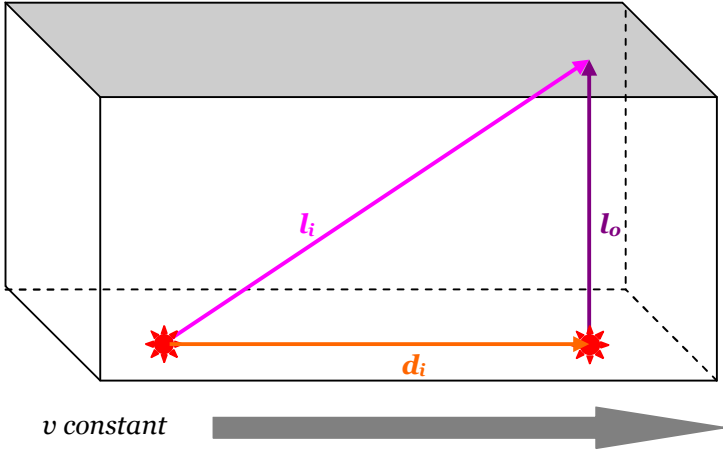
Along any continuous trajectory:



## Inertial time $t_i$

- $\gamma$  is the relativistic coefficient.
- The laser ray is emitted in any direction perpendicular to the motion.

Composition of the trajectories in the URM:



The locally quasi-Euclidean space-time permits the Pythagorean theorem:

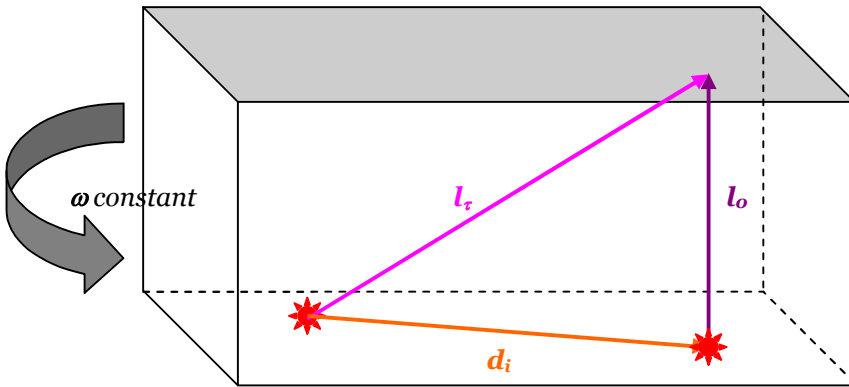
$$\begin{aligned}
 l_i^2 &= l_o^2 + d_i^2 \\
 (c\Delta t_i)^2 &= (c\Delta t_o)^2 + (v\Delta t_i)^2 \\
 \Delta t_i^2 (c^2 - v^2) &= c^2 \Delta t_o^2 \\
 \Delta t_i^2 (1 - \beta^2) &= \Delta t_o^2 \\
 \Delta t_i^2 &= \Delta t_o^2 / (1 - \beta^2) \\
 \Delta t_i &= \gamma \Delta t_o
 \end{aligned}$$

- $l_i = c\Delta t_i$  inertial laser ray trajectory, *i.e.* relative to a DP reference in URM at velocity  $v$ .
- $l_o = c\Delta t_o$  laser ray trajectory at rest, *i.e.* relative to an immobile DP reference.
- $d_i = v\Delta t_i$  inertial trajectory of the diode, *i.e.* in URM at velocity  $v$ .

## Tangential time $\tau$

- In UCM the tangential time coincides with the inertial one:  $\Delta\tau = \Delta t_i$ .
- The laser ray is emitted in direction of the vector angular velocity  $\omega$ .

Composition of the trajectories in direction tangential to the rotation:



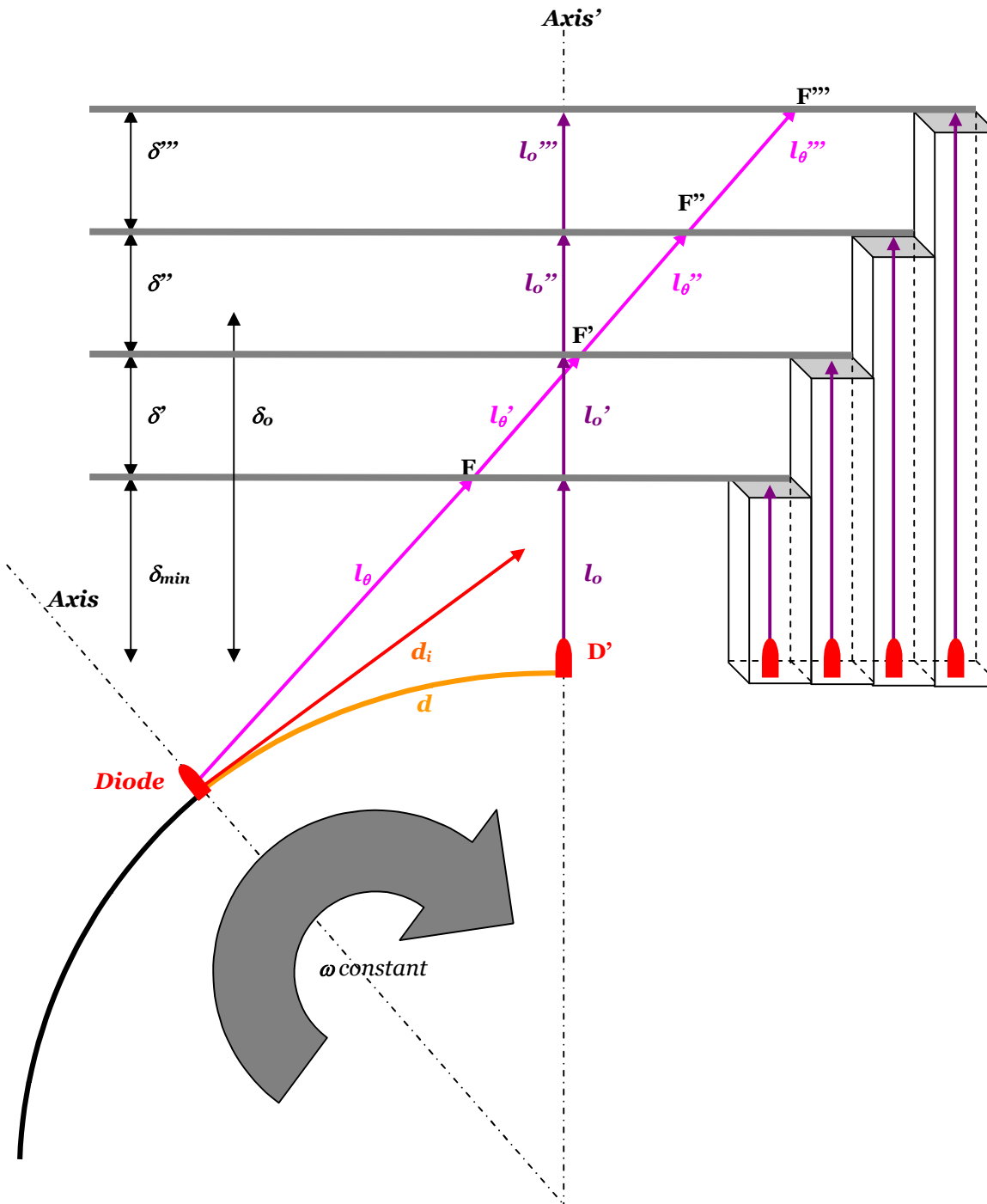
The locally quasi-Euclidean space-time permits the Pythagorean theorem:

$$\begin{aligned}
 l_\tau^2 &= l_o^2 + d_i^2 \\
 (c\Delta\tau)^2 &= (c\Delta t_o)^2 + (v\Delta\tau)^2 \\
 \Delta\tau^2 (c^2 - v^2) &= c^2 \Delta t_o^2 \\
 \Delta\tau^2 (1 - \beta^2) &= \Delta t_o^2 \\
 \Delta\tau^2 &= \Delta t_o^2 / (1 - \beta^2) \\
 \Delta\tau &= \gamma \Delta t_o \\
 \Delta\tau &= \Delta t_i
 \end{aligned}$$

- $l_\tau = c\Delta\tau$  tangential laser ray trajectory, *i.e.* relative to a DP reference in UCM at velocity  $\mathbf{v} = \omega \mathbf{r}$ .
- $l_o = c\Delta t_o$  laser ray trajectory at rest, *i.e.* relative to an immobile DP reference.
- $d_i = v\Delta\tau$  inertial trajectory of the diode in UCM, *i.e.* rectified in tangential direction.

# Angular time $\theta$

Composition of the trajectories in direction tangential to the rotation, at different diode-photodiode distances  $\delta$ :

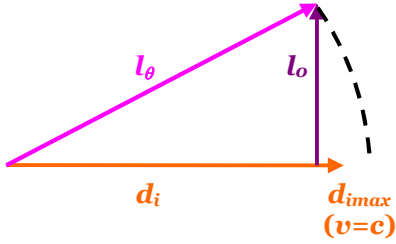


The laser ray is emitted in *radial* direction.

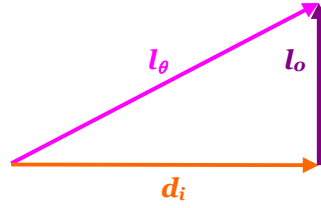
Denote  $\delta_\theta$  the diode-photodiode distance when:  $\Delta\theta = \Delta t_i$ .

Relationship between the angular time in UCM  $\Delta\theta$  and the one at rest  $\Delta t_o$ :

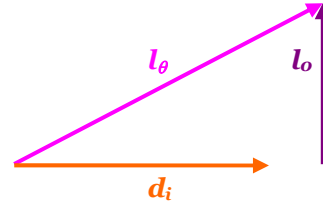
When  $\delta < \delta_o$ :



When  $\delta = \delta_o$ :



When  $\delta > \delta_o$ :



$l_\theta = c\Delta\theta$  angular laser ray trajectory, *i.e.* relative to a DP reference in UCM at velocity  $\mathbf{v} = \omega \mathbf{xr}$ .

$l_o = c\Delta t_o$  laser ray trajectory at rest, *i.e.* relative to an immobile DP reference.

$d_i = v\Delta\theta$  inertial trajectory of the diode in UCM, *i.e.* rectified in tangential direction.

The locally quasi-Euclidean space-time permits the Pythagorean theorem:

$$l_\theta^2 < l_o^2 + d_i^2$$

$$(c\Delta\theta)^2 < (c\Delta t_o)^2 + (v\Delta\theta)^2$$

$$\Delta\theta^2 (c^2 - v^2) < c^2 \Delta t_o^2$$

$$\Delta\theta^2 (1 - \beta^2) < \Delta t_o^2$$

$$\Delta\theta^2 < \Delta t_o^2 / (1 - \beta^2)$$

$$\Delta\theta < \gamma \Delta t_o$$

$$\Delta\theta < \Delta t_i$$

$$l_\theta^2 = l_o^2 + d_i^2$$

$$(c\Delta\theta)^2 = (c\Delta t_o)^2 + (v\Delta\theta)^2$$

$$\Delta\theta^2 (c^2 - v^2) = c^2 \Delta t_o^2$$

$$\Delta\theta^2 (1 - \beta^2) = \Delta t_o^2$$

$$\Delta\theta^2 = \Delta t_o^2 / (1 - \beta^2)$$

$$\Delta\theta = \gamma \Delta t_o$$

$$\Delta\theta = \Delta t_i$$

$$l_\theta^2 = l_o^2 + d_i^2$$

$$(c\Delta\theta)^2 > (c\Delta t_o)^2 + (v\Delta\theta)^2$$

$$\Delta\theta^2 (c^2 - v^2) > c^2 \Delta t_o^2$$

$$\Delta\theta^2 (1 - \beta^2) > \Delta t_o^2$$

$$\Delta\theta^2 > \Delta t_o^2 / (1 - \beta^2)$$

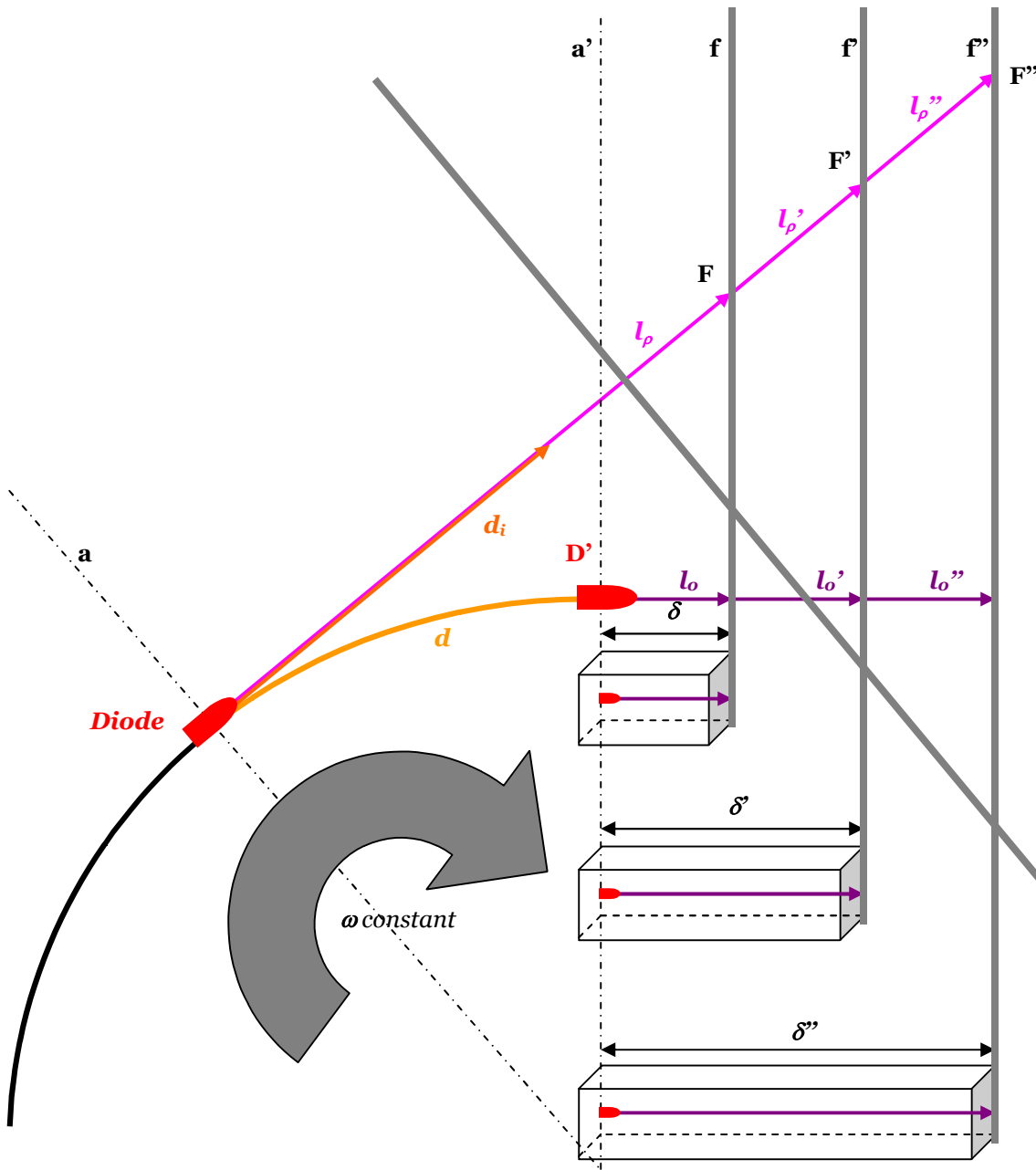
$$\Delta\theta > \gamma \Delta t_o$$

$$\Delta\theta > \Delta t_i$$

In UCM the angular time is:  $\Delta\theta < \Delta t_i$  beside;  $\Delta\theta > \Delta t_i$  far away, growing with the distance.

# Radial time $\rho$

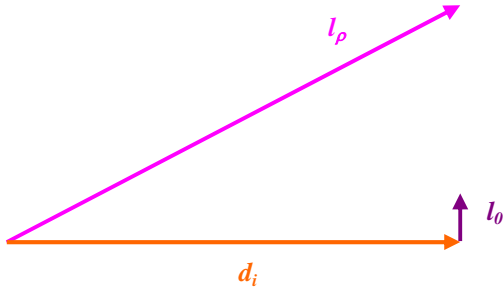
Composition of the trajectories in direction radial to the rotation, at different diode-photodiode distances  $\delta$ :



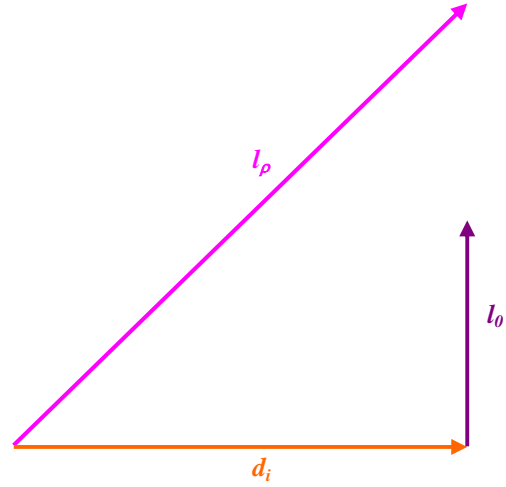
The laser ray is emitted in *tangential* direction.

Relationship between the radial time in UCM  $\Delta\rho$  and the one at rest  $\Delta t_o$ .

**Beside (short  $\delta$ ):**



**Far away (long  $\delta$ ):**



$l_\rho = c\Delta\rho$  radial laser ray trajectory, i.e. relative to a DP reference in UCM at velocity  $\mathbf{v} = \omega \mathbf{x}_r$ .

$l_o = c\Delta t_o$  laser ray trajectory at rest, i.e. relative to an immobile DP reference.

$d_i = v\Delta\rho$  inertial trajectory of the diode in UCM, i.e. rectified in tangential direction.

The locally quasi-Euclidean space-time permits the Pythagorean theorem:

$$\begin{aligned} l_\rho^2 &\gg l_o^2 + d_i^2 \\ (c\Delta\rho)^2 &\gg (c\Delta t_o)^2 + (v\Delta\rho)^2 \\ \Delta\rho^2 (c^2 - v^2) &\gg c^2 \Delta t_o^2 \\ \Delta\rho^2 (1 - \beta^2) &\gg \Delta t_o^2 \\ \Delta\rho^2 &\gg \Delta t_o^2 / (1 - \beta^2) \\ \Delta\rho &\gg \gamma \Delta t_o \\ \Delta\rho &\gg \Delta t_i \end{aligned}$$

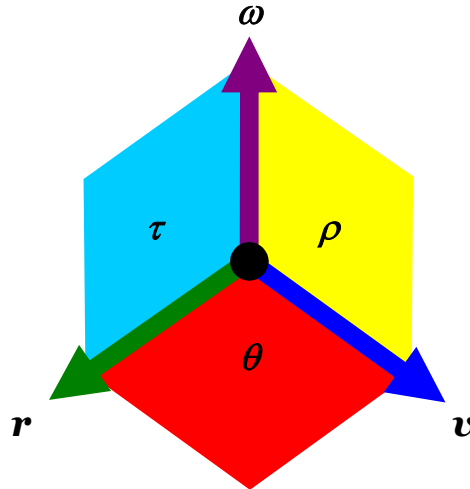
$$\begin{aligned} l_\rho^2 &> l_o^2 + d_i^2 \\ (c\Delta\rho)^2 &> (c\Delta t_o)^2 + (v\Delta\rho)^2 \\ \Delta\rho^2 (c^2 - v^2) &> c^2 \Delta t_o^2 \\ \Delta\rho^2 (1 - \beta^2) &> \Delta t_o^2 \\ \Delta\rho^2 &> \Delta t_o^2 / (1 - \beta^2) \\ \Delta\rho &> \gamma \Delta t_o \\ \Delta\rho &> \Delta t_i \end{aligned}$$

In UCM the radial time is:  $\Delta\rho > \Delta t_i$ , asymptotically decreasing towards  $\Delta t_i$  with the distance.

# The six-dimensional spacetime

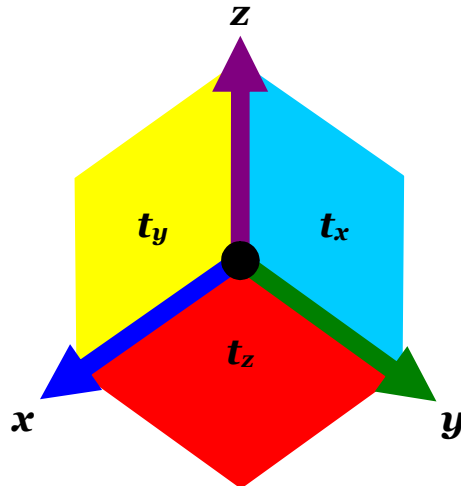
After introducing proper reference frames for an event in the 6D space-time, we should six-dimensionally extend: the Lorentz transformations, the squared invariant interval, the metric tensor, the quadratic form, the Ricci curvature tensor, the scalar curvature, the contracted Bianchi identities, the conservation equations, the Lagrangian of matter, the Einstein field equations, the scalar function and the variation principle.

## **6D instantaneous vectorial reference**



The three instantaneous vectors  $v, \omega, r$  and their relative planes  $\tau, \theta, \rho$  altogether constitute an instantaneous Cartesian reference system  $v\omega r\tau\theta\rho$  on whose orientations the following times are measured:  
 $\Delta\tau$ =*tangential time*, measured on the orientation perpendicular to  $v$ .  
 $\Delta\theta$ =*angular time*, measured on the orientation perpendicular to  $\omega$ .  
 $\Delta\rho$ =*radial time*, measured on the orientation perpendicular to  $r$ .

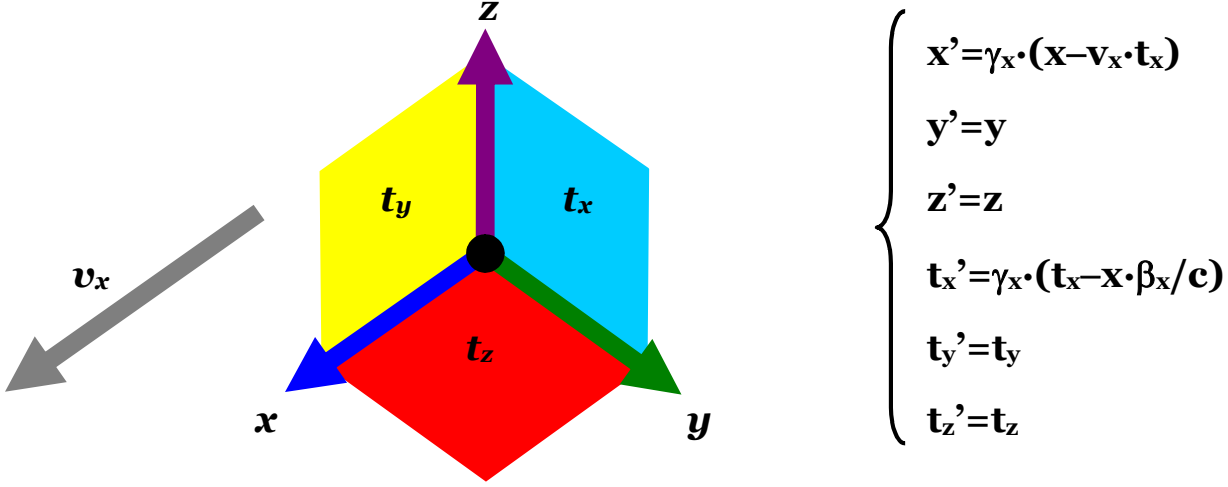
## **6D Cartesian reference in a flat space-time**



The three spatial axes  $x, y, z$  and the three temporal orientations  $t_x, t_y, t_z$  are mutually orthogonal and immobile. Each position  $P(x, y, z, t_x, t_y, t_z)$  is unique, *i.e.* representable without ambiguity. The three times  $\tau, \theta, \rho$  are in biunivocal correspondence with the three times  $t_x, t_y, t_z$ , because the measures in the instantaneous reference  $v\omega r\tau\theta\rho$  are univocally projected on the fixed reference  $xyzt_x t_y t_z$ .

## 6D Lorentz transformations

Let  $v_x$  be the constant velocity along the spatial axis  $x$ ; denote  $\beta_x = v_x/c$  and  $\gamma_x = (1 - \beta_x^2)^{-1/2}$ .  
The 6D Lorentz transformations have two further equations:  $t_y' = t_y$ ,  $t_z' = t_z$ .



## 6D invariant interval

Denote  $K$  and  $K'$  two inertial reference frames with parallel and equioriented coordinate axes.  
Let  $v_x$  be the relative velocity of  $K'$  respect to  $K$  (constant and parallel to the spatial axis  $x$ ).

Denote  $\beta_x = v_x/c$  and  $\gamma_x = (1 - \beta_x^2)^{-1/2}$ .

In  $K$  the event "1" is  $E_1(x_1, y_1, z_1, t_{x1}, t_{y1}, t_{z1})$  and the event "2" is  $E_2(x_2, y_2, z_2, t_{x2}, t_{y2}, t_{z2})$ .

In  $K'$  the event "1" is  $E_1'(x_1', y_1', z_1', t_{x1}', t_{y1}', t_{z1}')$  and the event "2" is  $E_2'(x_2', y_2', z_2', t_{x2}', t_{y2}', t_{z2}')$ .

<p><b>Event "1" in <math>K'</math>:</b></p> $\begin{cases} x_1' = \gamma_x \cdot (x_1 - v_x \cdot t_{x1}) \\ y_1' = y_1 \\ z_1' = z_1 \\ t_{x1}' = \gamma_x \cdot (t_{x1} - x_1 \cdot \beta_x / c) \\ t_{y1}' = t_{y1} \\ t_{z1}' = t_{z1} \end{cases}$	<p><b>Event "2" in <math>K'</math>:</b></p> $\begin{cases} x_2' = \gamma_x \cdot (x_2 - v_x \cdot t_{x2}) \\ y_2' = y_2 \\ z_2' = z_2 \\ t_{x2}' = \gamma_x \cdot (t_{x2} - x_2 \cdot \beta_x / c) \\ t_{y2}' = t_{y2} \\ t_{z2}' = t_{z2} \end{cases}$
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Let us verify the invariance of the six-dimensional interval  $\Delta\sigma^2 = \Delta x^2 + \Delta y^2 + \Delta z^2 - c^2(\Delta t_x^2 + \Delta t_y^2 + \Delta t_z^2)$  when the inertial reference frame changes.

**In  $K$ :**  $\Delta\sigma^2 = \Delta x^2 + \Delta y^2 + \Delta z^2 - c^2(\Delta t_x^2 + \Delta t_y^2 + \Delta t_z^2) = (x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2[(t_{x2} - t_{x1})^2 + (t_{y2} - t_{y1})^2 + (t_{z2} - t_{z1})^2]$

**In  $K'$ :**  $\Delta\sigma'^2 = \Delta x'^2 + \Delta y'^2 + \Delta z'^2 - c^2(\Delta t_x'^2 + \Delta t_y'^2 + \Delta t_z'^2) = (x_2' - x_1')^2 + (y_2' - y_1')^2 + (z_2' - z_1')^2 - c^2[(t_{x2}' - t_{x1}')^2 + (t_{y2}' - t_{y1}')^2 + (t_{z2}' - t_{z1}')^2]$

$$\Delta\sigma'^2 = [\gamma_x(x_2 - v_x t_{x2}) - \gamma_x(x_1 - v_x t_{x1})]^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2\{[\gamma_x(t_{x2} - x_2 \beta_x / c) - \gamma_x(t_{x1} - x_1 \beta_x / c)]^2 + (t_{y2} - t_{y1})^2 + (t_{z2} - t_{z1})^2\}$$

$$\Delta\sigma'^2 = \gamma_x^2[(x_2 - x_1) - v_x(t_{x2} - t_{x1})]^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2\{\gamma_x^2[(t_{x2} - t_{x1}) - (x_2 - x_1)\beta_x / c]^2 + (t_{y2} - t_{y1})^2 + (t_{z2} - t_{z1})^2\}$$

$$\Delta\sigma'^2 = \gamma_x^2[(x_2 - x_1) - v_x(t_{x2} - t_{x1})]^2 - \gamma_x^2\{c^2[(t_{x2} - t_{x1}) - (x_2 - x_1)\beta_x / c]^2\} + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2(t_{y2} - t_{y1})^2 - c^2(t_{z2} - t_{z1})^2$$

$$\Delta\sigma'^2 = \gamma_x^2[(x_2 - x_1)^2(1 - \beta_x^2) - (c^2 - v_x^2)(t_{x2} - t_{x1})^2] + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2(t_{y2} - t_{y1})^2 - c^2(t_{z2} - t_{z1})^2$$

$$\Delta\sigma'^2 = \gamma_x^2[(x_2 - x_1)^2 / \gamma_x^2 - (t_{x2} - t_{x1})^2 c^2 / \gamma_x^2] + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2(t_{y2} - t_{y1})^2 - c^2(t_{z2} - t_{z1})^2$$

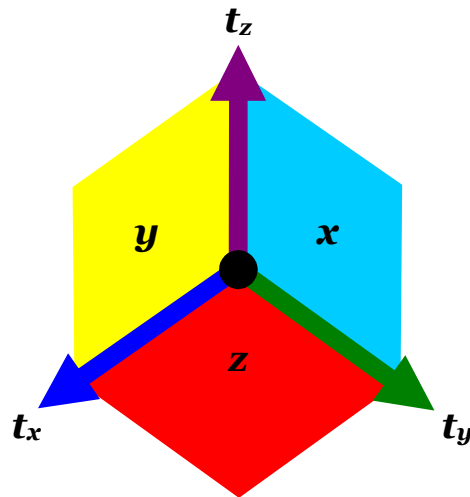
$$\Delta\sigma'^2 = (x_2 - x_1)^2 - (t_{x2} - t_{x1})^2 c^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2(t_{y2} - t_{y1})^2 - c^2(t_{z2} - t_{z1})^2$$

$$\Delta\sigma'^2 = (x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2(t_{x2} - t_{x1})^2 - c^2(t_{y2} - t_{y1})^2 - c^2(t_{z2} - t_{z1})^2$$

$$\Delta\sigma'^2 = (x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2 - c^2[(t_{x2} - t_{x1})^2 + (t_{y2} - t_{y1})^2 + (t_{z2} - t_{z1})^2]$$

$\Delta\sigma'^2 = \Delta\sigma^2$

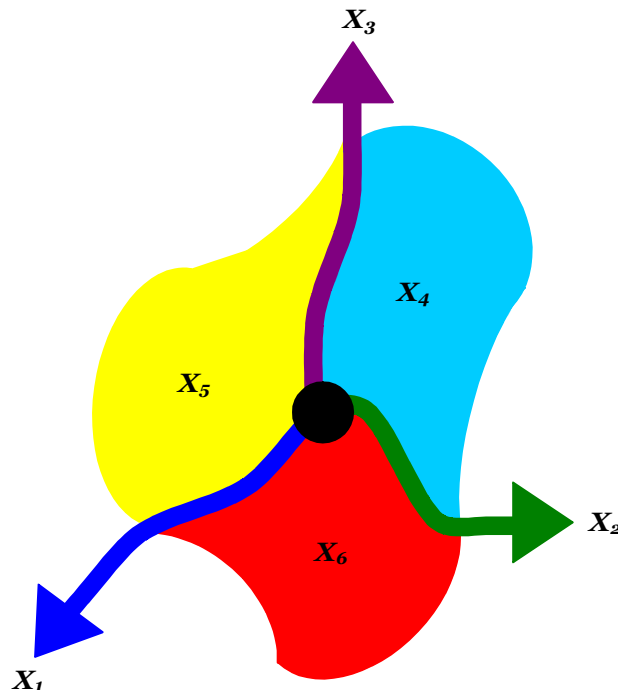
## *A meaningless opposite?*



The symmetrical Cartesian reference frame would consist of three temporal axes  $t_x, t_y, t_z$  and three spatial orientations  $x, y, z$  mutually orthogonal and immobile.

Such reference doesn't seem to have any physical reason to be introduced; anyway each position  $P(t_x, t_y, t_z, x, y, z)$  would be unique, *i.e.* representable without ambiguity. This apparently meaningless scenario could however be explored.

## *6D Gaussian reference in a curved space-time*



The three spatial lines  $X_1, X_2, X_3$  are not necessarily neither rectilinear nor mutually orthogonal and the three temporal surfaces  $X_4, X_5, X_6$  are not necessarily neither plane nor reciprocally orthogonal. The only condition is that each event  $E(X_1, X_2, X_3, X_4, X_5, X_6)$  is unique, *i.e.* representable without ambiguity.

The position  $P(x, y, z, t_x, t_y, t_z)$  is in biunivocal correspondence with the event  $E(X_1, X_2, X_3, X_4, X_5, X_6)$ . In fact, by keeping the relativistic assumption about the quasi-Euclidean nature of space-time continuum at local level, there is the biunivocal correspondence between the measures in any Cartesian reference  $xyzt_x t_y t_z$ . and the same taken in a Gaussian reference  $X_1 X_2 X_3 X_4 X_5 X_6$  in curved space-times locally almost flat.

# 6D General Relativity

If space and time are both three-dimensional, then:

- the metric tensor  $g_{\mu\nu}$  is six-dimensional:  $\mu, \nu=1,2,3,4,5,6$ ;
- the quadratic form  $ds^2=g_{\mu\nu}dx_\mu dx_\nu$  is six-dimensional:  $\mu, \nu=1,2,3,4,5,6$ ;
- the Ricci curvature tensor  $R_{\mu\nu}$  is six-dimensional:  $\mu, \nu=1,2,3,4,5,6$ ;
- the scalar curvature  $R$ , trace of  $R_{\mu\nu}$ , is 6D:  $R^6=R_a^a=R_{11}+R_{22}+R_{33}+R_{44}+R_{55}+R_{66}$ ;
- the contracted Bianchi identities  $\nabla^\mu(R_{\mu\nu}-1/2Rg_{\mu\nu})=0$  are 6D:  $\mu, \nu=1,2,3,4,5,6$ ;
- the conservation equations  $\nabla^\mu T_{\mu\nu}=0$  are six-dimensional:  $\mu, \nu=1,2,3,4,5,6$ ;
- the Lagrangian of matter is six-dimensional:  $L^6$ ;
- the Einstein tensor  $G_{\mu\nu}=R_{\mu\nu}-1/2g_{\mu\nu}R$  is six-dimensional:  $\mu, \nu=1,2,3,4,5,6$ ;
- the source tensor  $T_{\mu\nu}$  is six-dimensional:  $\mu, \nu=1,2,3,4,5,6$ ;
- the Einstein field equations  $G_{\mu\nu}=kT_{\mu\nu}$  are six-dimensional:  $\mu, \nu=1,2, \dots, 6$ ;
- the 6D equations  $G_{\mu\nu}=kT_{\mu\nu}$  are 36, reducible to 21 in case of symmetry;
- the relativistic scalar function  $J^4=L^4-R^4/2k$  is six-dimensional:  $J^6=L^6-R^6/2k$ ;
- the relativistic variation principle  $\delta\int J^4 \sqrt{g} d^4X=0$  is six-dimensional:  $\delta\int J^6 \sqrt{g} d^6X=0$ .

The six-dimensional source tensor  $T_{\mu\nu}$  is super-symmetrical, consisting of 4 quadrants each with 9 components (because the usual 4D energy density quadrant enlarges itself with 8 extra-components in 6D):

<b>Energy density</b>	<b>T<sub>00</sub></b>	<b>T<sub>01</sub></b>	<b>T<sub>02</sub></b>	<b>T<sub>03</sub></b>	<b>T<sub>04</sub></b>	<b>T<sub>05</sub></b>	<b>Energy flux</b>
	<b>T<sub>10</sub></b>	<b>T<sub>11</sub></b>	<b>T<sub>12</sub></b>	<b>T<sub>13</sub></b>	<b>T<sub>14</sub></b>	<b>T<sub>15</sub></b>	
	<b>T<sub>20</sub></b>	<b>T<sub>21</sub></b>	<b>T<sub>22</sub></b>	<b>T<sub>23</sub></b>	<b>T<sub>24</sub></b>	<b>T<sub>25</sub></b>	
<b>Momentum density</b>	<b>T<sub>30</sub></b>	<b>T<sub>31</sub></b>	<b>T<sub>32</sub></b>	<b>T<sub>33</sub></b>	<b>T<sub>34</sub></b>	<b>T<sub>35</sub></b>	<b>Momentum flux</b>
	<b>T<sub>40</sub></b>	<b>T<sub>41</sub></b>	<b>T<sub>42</sub></b>	<b>T<sub>43</sub></b>	<b>T<sub>44</sub></b>	<b>T<sub>45</sub></b>	
	<b>T<sub>50</sub></b>	<b>T<sub>51</sub></b>	<b>T<sub>52</sub></b>	<b>T<sub>53</sub></b>	<b>T<sub>54</sub></b>	<b>T<sub>55</sub></b>	

## Conclusions

According to my opinion, the commonly accepted version of space-time in four dimensions hides two unjustified assumptions:

- 1) there exists only one temporal coordinate;
- 2) the temporal coordinate is measured on a line like the spatial ones, although with imaginary values.

Through logical, epistemological and physical argumentations and recalling the independent contributions by other researchers about similar topics, this dissertation has explored a possible scenario where:

- 1) an event requires *three* time coordinates to be defined;
- 2) for measuring time a *surface* is a more effective geometrical entity than a line.

The main consequences of a three-dimensional time (instead of monodimensional) measured on mutually orthogonal surfaces (instead of axes) are the introduction of new six-dimensional reference frames in flat and curved space-time and the reformulation of Relativity equations in 6D.

# Bibliography

- Afriat, A., *The Paradox of Einstein, Podolsky and Rosen in Atomic, Nuclear and Particle Physics*, Plenum, 1998
- Bennett, C., *Precausal Quantum Mechanics*, «Physical Review», A36:4139-4148, 1987
- Bonacci, E., *General Relativity Extension*, Carta e Penna, 2006
- Bonacci, E., *Absolute Relativity*, Carta e Penna, 2006
- Bonacci, E., "Extension of Einstein's Relativity," Pisa, 93<sup>rd</sup> IPS Congress (2007), Atticon3691 I-C-1
- Bonacci, E., "Can time be three-dimensional?," Bari, 95<sup>th</sup> IPS Congress (2009), Atticon4955 VI-C-2
- Bonacci, E., *Extension of Einstein's Relativity*, Rome, Aracne n. 42, 2007
- Bonacci, E., *Beyond Relativity*, Rome, Aracne n. 43, 2007
- Bonacci, E., "Beyond Relativity," *Lectio Magistralis*, «L. Da Vinci» Terracina 2008, Auditorium
- Bonacci, E., "Praeter Relativitatem," *Lectio Magna*, «G.B. Grassi» Latina 2008, Aula Magna
- Bonacci, E., "Condensed matter properties in 6D," Rome, *Europhysics Conference Abstracts* Vol. 32F (2008), p. 74
- Bonacci, E., "The Principle of Reciprocity in Physics," *Salotto degli Autori* n. 23 (2008), p. 18
- Bonacci, E., "The meaning of Absolute Relativity," *Salotto degli Autori* n. 23 (2008), p. 24
- Bonacci, E., "Beyond Relativity," Cosenza, *Proceedings 18<sup>th</sup> Sigrav Congress* (2008)
- Bonacci, E., "On the General Relativity Extension," *Salotto degli Autori* n. 24 (2008), p. 23
- Bonacci, E., "Absolute Relativity," USA, *Cosmopolitan University Archives* (2008)
- Bonacci, E., "Extending Einstein's General Relativity," *Cosmopolitan University Archives* (2008)
- Bonacci, E., "The Reciprocity as Physical Law," USA, *Cosmopolitan University Archives* (2008)
- Bonacci, E., "New ideas on Theoretical Physics," USA, *Cosmopolitan University Library* (2009)
- Bonacci, E., "Relativity Extension," London, *Manuscript for The Institute of Physics* 1110424-29/04/2009
- Bonacci, E., "Is it possible to go beyond Relativity?," USA, *Cosmopolitan University Library* (2009)
- Chen, X., "Three Dimensional Time Theory: to Unify the Principles of Basic Quantum Physics and Relativity", ArXiv, 2005
- Dicke, R.H., *Interaction-free Quantum Measurements: a Paradox?*, «American Journal of Physics», 49:925-930, 1981
- Einstein, A., *Zur Elektrodynamik bewegter Körper*, Annalen Der Physik, 30 June 1905
- Einstein, A., *Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?*, Annalen Der Physik, 27 September 1905
- Einstein, A., *Die Grundlage der allgemeinen Relativitätstheorie*, «Annalen Der Physik», 49:69-822, 1916
- Einstein, A., et al., *Can Quantum-mechanical Description of Physical Reality be Considered Complete?*, Princeton, 1983
- Feynman, R.P., Wheeler, J.A., *Interaction with the Absorber as the Mechanism of Radiation*, «Rev. Mod. Phys.», 17:157-181, 1945
- Lunsford, D.R., "Gravitation and Electrodynamics Over SO(3,3)," Cern Archive, 2003
- Sparling, J.A., "Spacetime is spinorial; new dimensions are time-like," ArXiv, 2006
- Strnad, J., "On multidimensional time," 1980 *J. Phys. A: Math. Gen.* 13, L389
- Strnad, J., "Experimental evidence against a three-dimensional time," 1983 *Physics Letters A* 96(5), p. 231
- Strnad, J., "Three-dimensional time and quantum mechanics," 1982 *Lettere al Nuovo Cimento*, 33(9), p. 251
- Ziino, G., "More about three-dimensional time and wave mechanics: A reply to Strnad," 1983 *Lettere al Nuovo Cimento* 36(9), p. 255
- Ziino, G., "On a further argument in support to the conjecture of a three-dimensional time," 1985 *Lett. al Nuovo Cimento* 42(1), p. 35

# Webgraphy

- Bonacci, E., <http://xoomer.alice.it/enzobonacci/index.html>
- Bonacci, E., <http://it.youtube.com/user/EnzoBonacci>
- Bonacci, E., <http://atticon.sif.it/onlinepdf/atticon3691.pdf>
- Bonacci, E., <http://atticon.sif.it/onlinepdf/atticon4955.pdf>
- Bonacci, E., [www.sigrav.org/Material/Cosenza2008/Bonacci.pdf](http://www.sigrav.org/Material/Cosenza2008/Bonacci.pdf)
- Bonacci, E., [www.liceoterracina.it/ita/AREA DIDATTICA - FISICA Dalle origini alla relatività.pdf](http://www.liceoterracina.it/ita/AREA_DIDATTICA_-_FISICA_Dalle_origini_alla_relativita_.pdf)
- Bonacci, E., [http://grassi.deltaeffe.it/images/modulistica/Lectio Magna Oltre la Relatività.pdf](http://grassi.deltaeffe.it/images/modulistica/Lectio_Magna_Oltre_la_Relativita_.pdf)
- Bonacci, E., [www.cosmopolitanuniversity.ac/library/LectioDoctoralis.pdf](http://www.cosmopolitanuniversity.ac/library/LectioDoctoralis.pdf)
- Bonacci, E., [www.cosmopolitanuniversity.ac/library/Absolute Relativity by Enzo Bonacci.pdf](http://www.cosmopolitanuniversity.ac/library/Absolute_Relativity_by_Enzo_Bonacci.pdf)
- Bonacci, E., [www.cosmopolitanuniversity.ac/library/The Principle of Reciprocity by Enzo Bonacci.pdf](http://www.cosmopolitanuniversity.ac/library/The_Principle_of_Reciprocity_by_Enzo_Bonacci.pdf)
- Bonacci, E., [www.cosmopolitanuniversity.ac/library/Extension of Einstein's Special Relativity by Enzo Bonacci.pdf](http://www.cosmopolitanuniversity.ac/library/Extension_of_Einstein's_Special_Relativity_by_Enzo_Bonacci.pdf)
- Bonacci, E., [www.cosmopolitanuniversity.ac/library/Extension of Einstein's General Relativity by Enzo Bonacci.pdf](http://www.cosmopolitanuniversity.ac/library/Extension_of_Einstein's_General_Relativity_by_Enzo_Bonacci.pdf)
- Bonacci, E., [www.cosmopolitanuniversity.ac/library/New Ideas on Theoretical Physics by Enzo Bonacci.pdf](http://www.cosmopolitanuniversity.ac/library/New_Ideas_on_Theoretical_Physics_by_Enzo_Bonacci.pdf)
- Chen, X., <http://arxiv.org/abs/quant-ph/9902037>
- Chen, X., <http://arxiv.org/abs/quant-ph/0501034>
- Chen, X., <http://arxiv.org/abs/quant-ph/0505104>
- Chen, X., <http://arxiv.org/abs/quant-ph/0506176>
- Chen, X., <http://arxiv.org/abs/quant-ph/0510010>
- Lunsford, D.R., <http://doc.cern.ch/archive/electronic/other/ext/ext-2003-090.pdf>
- Sparling, G.A.J., <http://arxiv.org/abs/gr-qc/0610068>
- Sparling, G.A.J., <http://arxiv.org/abs/gr-qc/0610069>
- Sparling, G.A.J., <http://arxiv.org/abs/gr-qc/0612006>