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Mass of Inertia and Kinetic Energy (MIKE)

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Abstract :

Limitations of Special Relativity Theory can be found for example in the constant inertial mass and in the time dilatation. Presently offered hypotheses are based on the dilatation of the inertial mass, and on an uniform time. It is deduced a velocity additivity function, ***γ(u) = γ(v)+ γ'(W)- γ'(0),*** with results very close to Relativity predictions. Some mathematical properties of this formula are also studied here. And the main Relativity experiments (Michelson, Bertozzi, Fizeau for water) are reinterpreted in this work.

A. *PARADOXAL*

Before presenting an alternative theory, we will first give two difficulties we can identify within the current Special Relativity Theory (SRT).

1 The Constant Inertial Mass (in SRT)

Chapter 20 of Einstein's work « La relativité » [1] is entitled: « *L'égalité de la masse inerte et de la masse pesante comme argument en faveur du postulat de la Relativité Générale*»; i.e. the equality of the inertial mass and of the gravitational mass, as an argument in favour of the General Relativity postulate. This brought his successors to develop concepts of inertia 'without mass', 'longitudinal mass' or 'kinetic mass', each of them being understood as different from the inertial mass; all these terms are confused.

2 The Variable Time (in SRT)

According to Relativity, time is variable (with the velocity, from one reference frame to another). However, there is no 'direct' measure of that. A reversal of time, an 'imaginary' time (i.t), a dilatation or a contraction of time - all are only explanations of experiments, and not direct measures of these phenomena.

3 Paradoxes

One one hand, many discussions are done around the paradoxes of Relativity, as the referential frame at *c* velocity, the Langevin twins, particles without mass, the demonstrations of Lorentz formulas and even of simultaneity, etc. On the other hand, Relativity can explain many phenomenas that Newton mechanical can not explain. A trouble remains : Relativity has a variable time, and Quantum Mechanics has an invariable time ; and there is only a single physics world. Two opposite theories on the same topic of time remain incoherent.

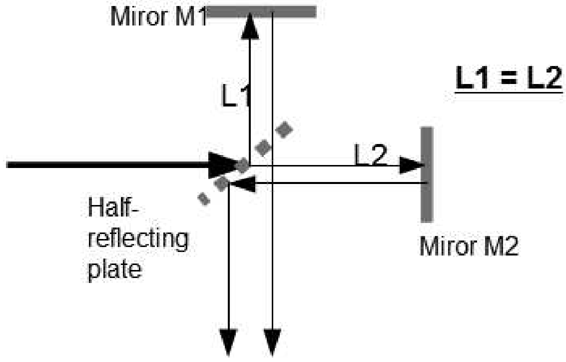
B. *PROOFS OF RELATIVITY ?*

The purpose is to present some experiments, usualy presented as a proof of Relativity, but which can be understood without Special Relativity Theory.

I. The Michelson-Morley Experiment on Light Velocity

a) The Facts

In the Michelson and Morley experiment [2], light spreads at the **same velocity** along (L1) and (L2)



b) Interpretation

This experiment is usualy given as a proof of Special Relativity. And yet…

This experiment has been done to prove the existence or not of aether ; if aether exists, the velocity of light along L1 should be different than along L2. Because it takes exatly the same time, this experiment only proves aether doesn't exist.

Since the duality wave-particle theory (this theory did not exist at Michelson age), it is accepted than the light can spread in the empty (without aether) space.

Photons running the same distance with the same velocity can simply be explained within Newton mechanical.

II. The atomic energy

a) The facts

Atomic bomb would be the blinding proof of the formula $E=m.c^2$. This formula means any mass *m* can be converted into energy *E*.

b) Interpretation

This formula can be deduced from Special Relativity Theory. But it also can be deduced **from Maxwell equations** [3] **without using a variable time** ; this formula is not specific to Relativity. And it's quite difficult to understand why in this conversion from mass to energy, there is a velocity of light, and why it's used the square (of the velocity). We have to keep in mind the *c* value can have 2 meanings :

- the *c* celerity of the photon
- a *C* transfer constant defined as $C = c^2 = 1/(\varepsilon_0\ \mu_0)$ *(1)*

So previous formula could better be written (without using a celerity):

$$m=\varepsilon_0.\mu_0.E \qquad (2)$$

Mass energy convertion can also be deduced without Relativity, and can be written without using the *c* light velocity

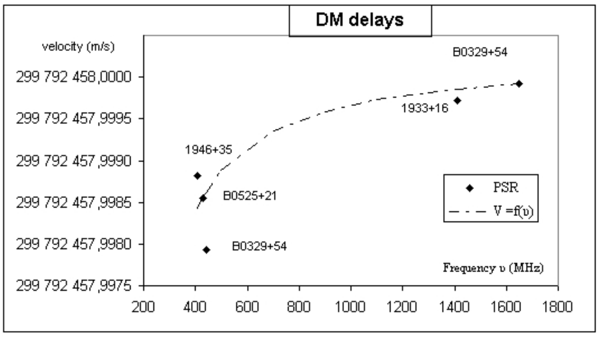
III. Pulsar Dispersion Measure (DM)

a) The facts

Pulsars (PSR) emit radiowaves. These radiowaves **arrives with a short delay** [4] vs the propagation of the light. This delay is given through the DM formula. And thanks to the distance from the pulsar to the Earth, we can calculate the velocity of the radiowaves. PSR radiowaves have not the *c* constant velocity (even in Relativity Theory)

b) Interpretation

Radiowaves are electromagnetics waves, like light. And in SRT, radiowaves should have the same velocity than light, i.e. the *c* celerity. To explain this short delay, the empty space is traditionnaly considered with an electronic fog which would affect the radiowaves (but not the lightwaves !).



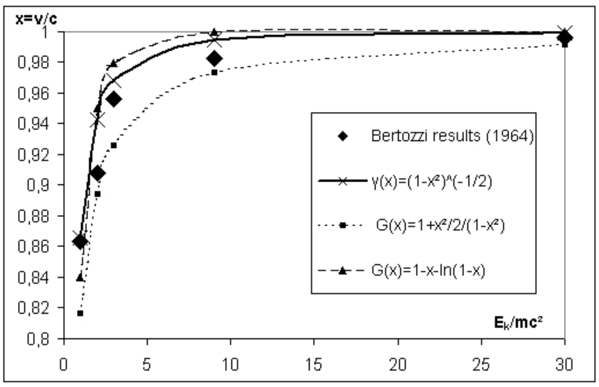
Velocity seems function of frequency, i.e. of kinetic energy

Present interpretation is to consider than the *V* velocities of electromagnetics waves as light are not constant and depend of their frequency, i.e. of their own kinetic energy.

IV. Bertozzi's experiment

a) The Facts

In Bertozzi's experiment [5], when a large voltage difference is applied to an electrical charge as an electron, velocity increases up to an assymptotic limit.



Velocity increases up to an assymptotic limit

b) Correlation

Closer curves seem to be :

- $G = 1+(v/s)^2/2/(1-v^2/s^2)$ *(3)*
- or $G = 1-v/s-\ln(1-v/s)$ *(4)*
- or $G = (1-v^2/c^2)^{-0.5}$ *(5)*
- or an other one

with a kinetic energy defined as

$$\Delta E_k = G.\ m_g\ .c^2 \qquad (6)$$

C. *MIKE THEORY*

I. Postulate

1 The Relativity postulates

STR is based on two postulates :

- the general Galilean postulate that the laws of physics have the same form in all uniform motion frame of reference
- velocity of light is a constant in the empty space in all frame of reference, and this constant is called the c celerity

The time dilatation, the impossibility of supraluminic velocities, the equality of inertial mass and of gravitationnal mass are consequences of SRT.

But there is also a paradox even in these 2 postulates together : in a referential frame moving at (c-0.001) m/s, photons travel at c celerity ; and in an other referential frame moving at exactly c m/s, the same photons don't move anymore ; and this whatever the direction of the photons are vs the last referential frame !

Thus the second postulate of STR, constant velocity of light, is hereafter given up.

2 MIKE postulate

The new postulate is inertial mass to be variable and growing with the energy, or with the velocity, up to an infinite value :

$$\boldsymbol{m_i = T_k\, G(v)\, m_g} \qquad (7)$$

with :

- m_g body gravitational mass ; it's a static mass which measures the attractivity to the gravity.
- m_i inertial mass : it's a dynamic mass which measures the modification of movement.
- v is the body velocity in the reference frame
- k is the name of the reference frame
- $G(v)$ is a variable coefficient in function of the velocity of the body
- T_k is a transfer coefficient to be determined in each reference frame.

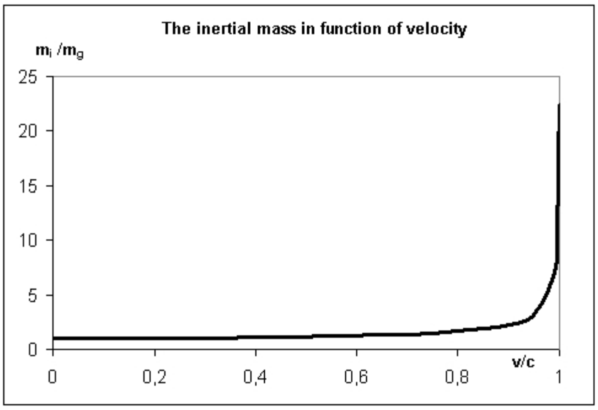
3 Comments

$$m_i / m_g = T_k\, .G(v) \qquad (7)$$

Due to Bertozzi experiment : $G(v) = (1\text{-}v^2/c^2)^{-0.5}$ (8)

if $T_k=1$ $\quad m_i / m_g = (1\text{-}v^2/c^2)^{-0.5}$ (9)

A part of the received energy is changed into the inertial mass m_i.



Graph to illustrate the increasing of the inertial mass

To precise, the link between the two masses would be : $m_g.g = m_i.a$ *(10)*
with a for acceleration and g for gravity attractivity, except that

- in Newtonian mechanics and in Relativity Theory: $m_g = m_i$,
- and in presently Mass of Inertia and Kinetic Energy (MIKE) theory: $\boldsymbol{m_g \neq m_i}$

II. Definition and coefficients

1 Definition

$\boldsymbol{E_k}$, a global kinetic energy, incorporating the inertial mass m_i, is defined as :

$$\boldsymbol{E_k = m_i S = m_i s^2} \quad (11)$$

with

- m_i inertial mass (as defined herebefore)
- S transfer constant ($S=s^2$)
- s assymptotic speed (to be determined hereafter)

2 Determination of the *s* assymptotic speed

a) Permeability and permittivity

If we suppose $s = (\varepsilon_0.\mu_0)^{-1/2}$ with *(12)*

- $\mu_0 = 4\, \Pi\, 10^{-7}\ [kg.m.A^2.s^{-2}]$ *(13)*
- $\varepsilon_0 \approx 1/(36\, \Pi\, 10^9\ )[F.m^{-1}]$ *(14)*

$s \approx 3.10^8\ m/s$, wich would give s greater than c photon celerity of about $1+10^{-3}$ factor (0.1%)

b) X-rays

For low energy electromagnetic waves (radio waves), it has been established (§B.III.b) that velocity is lower than c. And for high energy electromagnetic waves (X-rays), it has been established [6] that velocity is greater (!) than c, of about $1+10^{-6}$ factor.

So s could be equal to $c(1+10^{-6})$, and attributing a mass to the photon, we could get a good correlation using the formla $\Delta E_k = [(1-v^2/s^2)^{-0.5} - 1]\ m_g\, c^2$ *(15)*

c) Neutrinos

With the SN 1987A, it has been measured [7] Mev neutrinos coming 3 hours before the arrival of ev photons. It could be explained by a neutrino celerity 0.6 m/s higher than photon celerity, which would give s close to $c(1+10^{-9})$.

d) Result

In these cases, we could confirm $\boldsymbol{s \approx c \quad with \quad s \geq c}$ *(16)*

3 Determination of *G(v)*

The difference of global kinetic energy from a body going from 0 to v velocity is :

$$\Delta E_k = T_k\, G(v)\, m_g\, s^2 - T_k\, G(0)\, m_g\, s^2 \quad (17)$$

At low velocities, it’s well know than $\Delta E_k = ½\, m_g\, v^2$ *(18)*

In it’s own reference frame, it’s supposed $T_k=1$ *(19)*

and if $G(0) \approx 1$ => $[G(v)-1]s^2 \approx ½\, v^2$ *(20)*

$G(v) \approx 1 + ½\, v^2/s^2$ when v<<s *(21)*

So $G(v) = 1 + ½\, v^2/s^2 + g(v)$ for all v with *(22)*

- $limit\ G(v)-1 = ½\, v^2/s^2$ when $v << s$ *(23)*
- $limit\ G(v)-1 = +\infty$ when v close to s *(24)*

Several solutions can exist, but it is chosen here $G(v) = \gamma(v)$ with $\gamma(v) = (1-v^2/s^2)^{-1/2}$ *(25)*
due to the Bertozzi’s results (§ B.IV).

III. Velocities additivity demonstration

a) Conventions in this work

- observer's referential topics marked with small letters (*k, u, v,* m_i) and with continuous lines,
- other reference topics marked with capital letters (*K, W, M,...*) and with dotted lines.

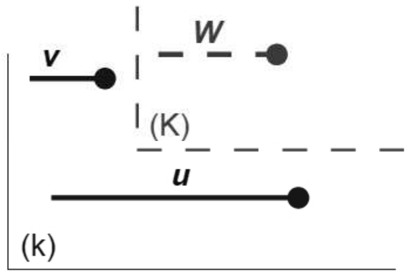
b) General demonstration

Velocity can be given to a body in a reference frame (k) in at least 2 ways:

1) supply energy in one step, in order that the body immediately reach the velocity in the (k) reference frame, or

2) supply energy in two steps (or more):

- first step in order to reach the *v* velocity in the (k) observer's reference frame, (K) velocity being v in the (k) reference frame.
- second step in order to reach the *W* velocity in the (K) reference frame, with *W* determined such that the body reaches *u* velocity in the (k) reference frame.



2 reference frames : (k) and (K)

As the global energy is conserved, it is possible to compare the first way (energy supplied in one step) with the second way (energy supplied in two steps):

$$\Delta E_k(u_{/(k)}) = \Delta E_k(v_{/(k)}) + \Delta E_k(W_{/(K)}) \qquad (26)$$

where the subscript /(k) identifies the frame (k) in which the body has gone from nil velocity to velocity *u*.

$$A_k[G(u)-G(0)]m_g s^2 = T_k[G(v)-G(0)]m_g s^2 + T_K[G(W)-G(0)]m_g s^2 \qquad (27)$$

Gravitational mass is the same in the two reference frames (k) and (K):

$$m_g = M_g \qquad (28)$$

and given

$$T = T_K / T_k \qquad (29)$$

and $G(0) = 1$ as previously supposed Eq.23

$$\boxed{G(u) = G(v) + [G(W)-1].T \qquad (30)}$$

or, with G'=G.T

$$\boxed{G(u) = G(v) + G'(W) - G'(0) \qquad (30\ bis)}$$

c) determination of T

- In the probable case where $G(v) = \gamma(v)$

$$(1+u^2/s^2)^{-1/2} = (1+v^2/s^2)^{-1/2} + T[(1+W^2/s^2)^{-1/2})-1] \qquad (31)$$

- When v<<s and W<<s,

$$(1+u^2/2s^2) = (1+v^2/2s^2) + T[(1+W^2/2s^2))-1] \qquad (32)$$

$$u^2 = v^2+TW^2 \qquad (33)$$

For low velocities, Newton's formula is $u = v+W$ (34)

implies $u^2 = v^2+W^2+2vW = v^2+W^2(1+2v/W)$ (35)

so $T = 1+2v/W$ (36)

- When v≈s and W≈s,

$$(1+s^2/s^2)^{-½} = (1+s^2/s^2)^{-½} + T[(1+s^2/s^2)^{-½})-1] \qquad (37)$$

needs $T \neq +\infty$

- This *T* value determined in two particular cases should be equal in general to

$$T = 1+2v/W+t(v;W) \qquad \text{with for } t \text{ :} \qquad (38)$$

- *limit t(v;W)=0* when *v* and *w* tend to *0* *(39)*
- *limit t(v;W)* ≠ +∞ when *v* and *W* tend to +∞ *(40)*

A possible solution is $\boldsymbol{T = 1+2v/W}$ ***(41)***

Remark : an other possible solution would have been $T=(1+v/W)^{½}$, or something else *(42)*

d) Specific formula (when *G*=*γ*)

Another way to write additivity formula is u such that

$$\boxed{\gamma(u) = \gamma(v)+ \gamma'(W)- \gamma'(0) \qquad (43)}$$

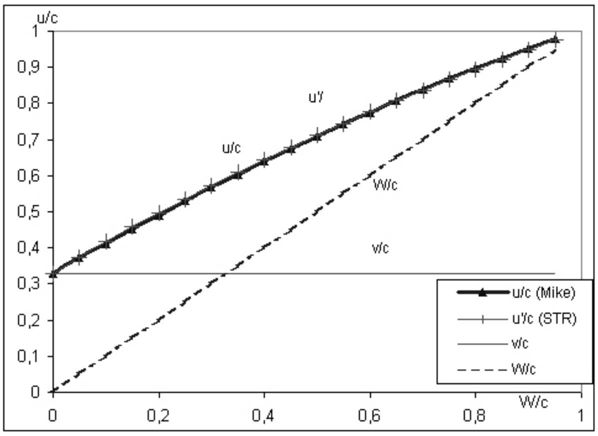
with $\gamma'(W) = T\,\gamma(W)$ *(44)*

or $(1+u^2/s^2)^{-½} = (1+v^2/s^2)^{-½} + (1+2v/W)[(1+W^2/s^2)^{-½})-1]$ *(45)*

$$u = c\sqrt{1-\left[\frac{1}{\sqrt{1-v^2/s^2}}+\left(\frac{1}{\sqrt{1-W^2/s^2}}-1\right)\left(1+2v/W\right)\right]^{-2}} \qquad (46)$$

e) Comparison with Relativity formula:

Hereafter a comparative graphic for velocities/*c* in function of *W/c*, for example with *v/c=0.33* (*i.e. v* =100,000 km/s, or 360,000,000 km/h) :



The two additivity formulas, u/c (Mike) and u'/c (Relativity), give very close results!

In practice, if we take a GPS satellite velocity, *v*=4,000 m/s (or 14,400 km/h), v/s = 1.33×10^{-5}:

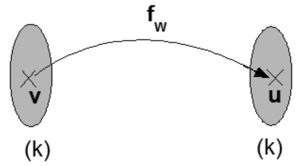
- for *W*=75,000 m/s (or *W*=270,000 km/h), difference between *u* and *u'* is 0.0001%
- for *W*=270,000 m/s (or *W*=972,000 km/h), difference between *u* (Mike) and *u'* (Relativity) is 0.0001%

The difference between the two formulas is about 0.0001%.

IV. Mathematical properties

1 Terminology

Because the previous formula is closer to a functions composing than to a vector addition, it is called velocities ‘**additivity function’**:



it’s even a « right side » ***external binary operation*** [10], *from (k)*x*(K) to (k) :*

$$(k) \times (K) \qquad (k)$$
$$(v\,;\,W) \text{-------------}> \quad u = f_W(v) = v \neg W \qquad (47)$$

$\neg$ *is a right side because the element W of the external set (K) is written on the right*

2 Permutation

To go to velocity *W* in a (K) reference frame moving at velocity *v* in the (k) reference frame is equivalent to go to *v’* velocity in a (k') reference frame moving at *W* velocity in the (K) reference frame, *v’* defined in order to get *u=U*) :

$$\forall\, (u = v \neg W)\ \exists\, v' \in (k)\ \big|\, U = W \neg v' \text{ with } u=U \qquad (48)$$

3 Neutral element

For *W=0*, *u=v* (whatever *v* may be). So there exists a neutral additivity function: f_0

$$\forall\, v \in (k),\quad v \neg 0 = v \qquad (49)$$

4 Reverse

To each *v* velocity in (k) reference frame, there exists a *V* velocity in (K) reference frame: *V=-v* such that *u=0.*

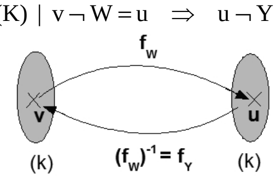
$$\forall\, v \in (k)\quad \exists V \in (K) \text{ with } V=-v \,|\, v \neg V = o \qquad (50)$$

5 Inverse

Definition: $(f)^{-1}$ to be the inverse function such that $(f)^{-1}[f(v)]=v$

To each *W* velocity in (K) reference frame, there exists a *Y* velocity in (K) reference frame such that $f_Y=(f_W)^{-1}$

$$\forall\, W \in (K)\quad \exists Y \in (K)\ |\ v \neg W = u \ \Rightarrow\ u \neg Y = v \qquad (51)$$



For example : $W=0.25s\ \ Y=-0.505s \ |\ 0.5s \neg 0.25s = 0.725s$ and $0.725s \neg -505s = 0.5s$

6 Exo-Commutativity

“Exo” for external data operation

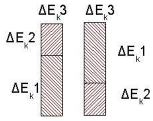
$[v \neg W = u] \in (k)$ but $[W \neg v = U] \in (K)$

(k) is different of (K), $\neg$ is not exo-commutative

Additivity function is not either commutative:

$[f_W(v)] \in (k)$ but $[F_V(W)] \in (K)$

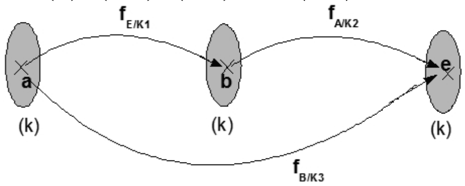
But it is commutative on global kinetic energy :



$$\Delta E_k 3 = \Delta E_k 1+\Delta E_k 2= \Delta E_k 2+\Delta E_k 1 \qquad (52)$$

7 Exo-associativity

Given four reference frames: (k), (K1), (K2) and (K3) :



$$\forall E\in(K1)\ \forall A\in(K2)\ \exists B\in(K3)\ |\ [u = (a\neg E)\neg A] \Rightarrow [a \neg B = u] \qquad (53)$$

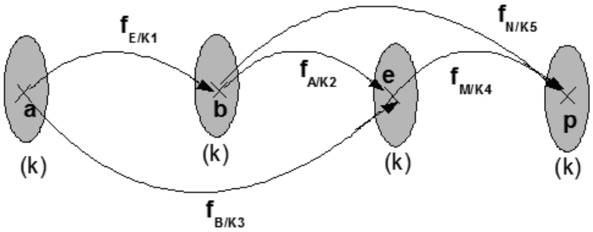
but if D=E $\neg$ A, there is no reason than D = B

Additivity on $\neg$ is not Exo-associative

8 Associativity of functions

Given six reference frames: (k), (K1), (K2), (K3), (K4) and (K5). Fonctions additivity is associative:

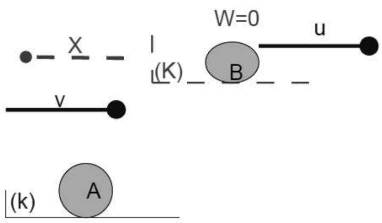
$$f_M\ [f_B(a)] = f_N\ [f_r(a)] \qquad (54)$$



$$u = (a\neg E)\neg N = (a \neg B) \neg M = [(a\neg E)\neg A]\neg M \qquad (55)$$

Remark : $v = a\neg(E\neg N)$ would be an other velocity

9 **Physical consequences of § C.IV.3 / neutral element**



If a body B [linked to (K)] is moving with an uniform *v* velocity compared to an other body A [linked to (k)], so A moves with an uniform velocity *X* compared to the body B, with *X*=-*v*.

Thus **<u>this formula respects the Galilean symmetry on the reference frames</u>**

D. *FIZEAU EXPERIMENTS*

1 Fizeau's results

a) Context :

At the end of the XIXth century, main question was to establish the existence of the aether. A way was to studied the influence of motion of the medium on the velocity of light.

Newtonian prediction (without aether) was proportionnal to *v* velocity of the medium

In 1881 Fizeau and Fresnel's prediction (with aether) was proportional to $v(1-1/n^2)$

b) The result:

In 1886, Michelson and Morley studied [8] the displacement of the central white frange and confirmed the increment of velocity was not equal to the velocity of the medium but depended of the index of refraction of the medium in $(1-1/n^2)$; correlation between this prediction et experimental results was less than (0.437/0.434 =) 1%, which is very accurate with XIX's experimental means.

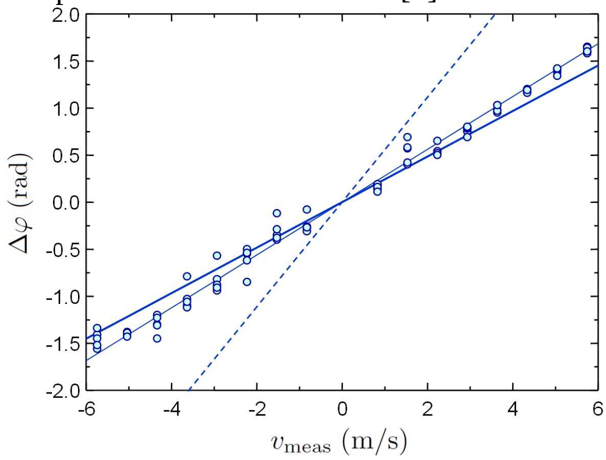
Curiously it even seemed probable to Michelson and Morley [8] that an other expression $v[1-1/n^2+(1/n^2)(a/a+b)]$ could be even more precise than Fizeau and Fresnel's prediction…

And if this experiment was a proof of SRT, they should rather have found in $v(1-1/n^2)/(1-v^2n^2/c^2)$

2 Contemporary results

a) The Facts:

In 2011, using an inexpensive setup but all the same laser beam, an undergraduate laboratory measured again Fizeau's experiment with such results [9]:



Extract of http://arxiv.org/abs/1201.0501

- thin solid line : linear fit, giving a slope of 0.274 rad.s/m
- thick solid line : relativistic theoretical expression (0.248)
- dashed line : Newton theoretical expression

b) Comments:

* "**We observe that the experimental points almost systematically lie above the relativistic value**" [10]: the relativistic slope without correction (thick solid line) is 9% lower than the experimental slope (thin solid line) !

* The relativistic prediction multiplied by a correction factor including dispersion, yields a slope of 0.299 rad.s/m, not shown on the figure herebefore: the agreement between the corrected relativistic and the experimental values is (0.299/0.274=) 9%!!

* ± 9% is not negligible, and is very different of ± 1% precision found more than a century ago: without or with correction, relativitic prediction doesn't seem to match exactly with experimental datas. It means differences cames either from the experimental measures, either from their corrections (for example the 1.16 coefficent used by Michelson for a 28 mm diameter and used here for a 8 mm diameter !) and/or from the relativistic prediction.

3 MIKE prediction

a) The Facts:

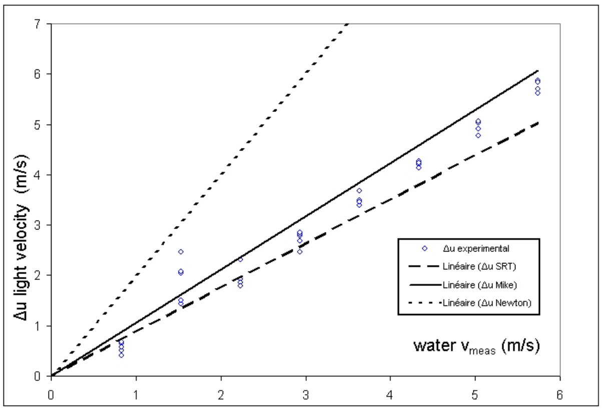
Previous experimentals datas are converted from 'radian' to 'difference of light velocities' to be more concret. We use the formula $\Delta p=\Delta\delta/\lambda$ (56)

$$\Delta p=2L(n_1-n_2)/\lambda \quad \text{with } n_1=c/u_1 \text{ and } n_2=c/u_2 \qquad (57)$$

$$\Leftrightarrow \ \Delta u = u_1\, u_2\, \lambda\, \Delta p / (2\, c\, L) \qquad (58)$$

$$\Leftrightarrow \ \Delta u \approx (\lambda\, c\, \Delta p)/(2\, L\, n^2) \qquad (59)$$

with $\lambda=532$ nm, $c= 299792458$ m/s, $L=2$ m, $n=1{,}336$ and $\Delta p= \Delta P/(2\Pi)$



Fizeau experiment results

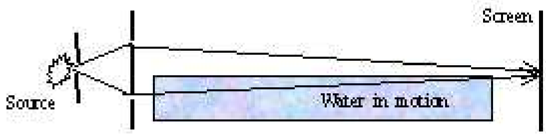
- *thick dashed line : NEWTON theoretical expression*
- *thin dashed line : RELATIVISTIC theoretical expression*
- *thin solid line : MIKE theoretical expression*
-

b) Comments :

MIKE prediction (including refraction correction) is a bit closer of experimental datas than SRT (without corrections).

Of course, if it is added a velocity correction, it will less correlate; in this case, we would have the same conclusion than before, i.e. the difference could come either from the experimental measures, either from the MIKE formula. In the first case, it will be necessary to check the underlying hypothesis there is no light interferences in the tube (2 rays on the same axis in the same pipe to be equivalent to 2 parallel rays into 2 different pipes). In this second case, discrepancy could not necessary came from the postulate itself or from the reasoning but maybe also on the choosen correlations as $s=c$ *(Eq.16)*, $G=\gamma$ *(Eq.25)* or $T=1+2v/W$ *(Eq.41)*.

Proposed experiment :



2 parallel rays into 2 different pipes

E. *CONCLUSION*

Relativity has a variable time, and Quantum Mechanics has an invariable time. Because there is only a single physics world, a velocities additivity theory without time dilatation would be in coherence with Q.M.

The main experiments of the Relativity can also be explained without time dilatation, only applying Lorentz factor to the inertial mass (instead of applying it to the time), as in Michelson or in Bertozzi experiments. It could also interpretate some physical phenomenas as a lower velocity of radio waves or a slightly higher velocity of neutrinos.

***G(u) = G(v) + [G(W)-1].T* is the Mass of Inertia and Kinectic Energy (MIKE) formula.**

The difference between Relativity predictions and present MIKE predictions is very light (about 0.0001%).

If we have noticed that Relativistic prediction, without or with corrections, doesn't seem to match exactly with Fizeau's experimental results, we'll only say than without results of the proposed experiment, it would be yet prematured to conclude on MIKE predictions.

Anyway, instead of a paradoxal variable time, an approach based on Kinetic Energy could go into thoroughly ; and an idea can generate another idea.

References

1 – la relativité from Albert Einstein – Édition Payot 1979
2 – Michelson : http://semsci.u-strasbg.fr/michmor.htm ;
http://www.sciences.univ-nantes.fr/sites/jacques_charrier/tp/michelson/reglm1m2.html
3 – Maxwell: http://www.astrosurf.com/trousnoirs/demonstrationE.html
4 – Pulsar delay PSR B0329+54: http://www.pa0ply.nl/pulsar.htm -
http://www.gb.nrao.edu/sd03/talks/jcordes.single-dish.school.2003.pdf
5 – Bertozzi : http://muj.optol.cz/richterek/data/media/ref_str/bertozzi1964.pdf
6 – Xrays: http://hal.archives-ouvertes.fr/docs/00/20/52/11/PDF/ajp-jphysrad_1925_6_7_228_0.pdf
http://en.wikipedia.org/wiki/Refractive_index#cite_note-CXRO-9
7 – SN 1987A: http://fr.wikipedia.org/wiki/SN_1987A
8 – Original Fizeau's experiment: http://www.orgonelab.org/EtherDrift/Fizeau1851.pdf –
http://en.wikisource.org/wiki/Influence_of_Motion_of_the_Medium_on_the_Velocity_of_Light
9 – 2011 Fizeau's experiment : http://arxiv.org/abs/1201.0501
10 – External binary operation : http://en.wikipedia.org/wiki/External_(mathematics)