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DOES DOUBLE BETA DECAY RATE DEPEND ON TIME?

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DOES DOUBLE-BETA DECAY RATE DEPEND ON TIME?

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I. INTRODUCTION

The time variation of fundamental constants been an active subject to research since the introduction of the Large Number Hypothesis (LNH) by **P.A.M. Dirac** in 1937.

Present motivations:

1) Theory which attempt to unify gravity and other fundamental forces:

- Kaluza-Klein theories;
- superstring theories;
- massless dilaton models

cosmological solutions in which the low-energy fundamental constant vary with time

2) Time variation of **G** and **c** (speed of light) as a solution to cosmological puzzles (Phys.Rev. D59(1999)043515; 043516; ……)

3) Possible experimental evidence:

a) J.K. Webb et al. $^{1999\text{-}2003}$ ⇒

It was found that α was smaller at earlier epochs ⇒

$\mathbf{\Delta\alpha/\alpha = (-0.54 \pm 0.12)\cdot 10^{-5}}$ for $0.2 < z < 3.7$

(But this is in conflict with two recent results:

$\mathbf{\Delta\alpha/\alpha = (-0.06 \pm 0.06)\cdot 10^{-5}}$ for $0.4 < z < 2.3$ (S.Srianand et al.,
2004)

$\mathbf{\Delta\alpha/\alpha = (0.01 \pm 0.17)\cdot 10^{-5}}$ for $z = 1.15$ (R. Quast et al.,
2004))

b) Oklo Natural Reactor (2 billion years ago):

$\mathbf{\Delta\alpha/\alpha = (0.88 \pm 0.07)\cdot 10^{-7}}$ (Y. Fujii, 2000-2003)

$\mathbf{\Delta\alpha/\alpha = (0.44\,^{+15}{}_{-7})\cdot 10^{-7}}$ (S.K. Lamoreaux,
J.R. Torgerson 2004)

[Best previous limits:

$\mathbf{\Delta\alpha/\alpha < 1.2\cdot 10^{-7}}$ (T.Damour and F. Dyson, 1996)

$\mathbf{\Delta\alpha/\alpha < 1\cdot 10^{-8}}$ (Y. Fujii, 2000)]

c) 2β-decay (A. Barabash, 1997-2003)

Decay rate depends on time? (in ^{130}Te and ^{82}Se) ⇒

$\mathbf{\Delta G_F/G_F \approx -(0.05\text{-}0.3)}$ **(or** $\mathbf{\Delta\eta/\eta \approx (0.02\text{-}0.15)}$ **)**

PRESENT LIMITS ON WEAK INTERACTION CONSTANT TIME VARIATION

The Oklo bound - **$|\Delta G_F|/G_F < 0.02$** ($\Delta G_F = G_F^{Oclo} - G_F^{now}$)

Big Bang nucleosynthesis - **$|\Delta G_F|/G_F < 0.06$**

^{40}K decay rate - **$|G_F/G_F| < 0.1$**

Remark: all these limits were obtained with **NON-NATURAL** assumption that other fundamental constants are stable.

II. 2β-DECAY AND TIME VARIATION OF G_F.

$$(A,Z) \rightarrow (A,Z+2) + 2e^- + 2\nu$$

2β(2ν)-decay process presents the special interest in the framework of fundamental constants time variation problem.

β-decay - **$T_{1/2}^{\beta} \sim G_F^{-2}$**

2β-decay - **$T_{1/2}^{2\beta} \sim G_F^{-4}$** (2β-decay is second order process of weak interactions)

This is why **2β**-decay can give additional (and may be **unique!**) information about time variation of **G_F**.

(Age of minerals, age of Earth ⇒ β and α decays!!!)

III. COMPARISON OF “PRESENT” and “PAST” 2β-DECAY RATES FOR ^{130}Te ^{82}Se AND ^{96}Zr

1. ^{82}Se.

$$^{82}\mathrm{Se} \rightarrow {}^{82}\mathrm{Kr} + 2e^{-} + 2\nu$$

“Present” - $T_{1/2} = (0.9 \pm 0.1)\cdot 10^{20}$ y
(world average value)

⇓

“Past” value $T_{1/2} = (1.3 \pm 0.05)\cdot 10^{20}$ y (T. Kirsten'83)

(geochemical experiments) (average value for 17 measurements; age of samples are from $8\cdot 10^{7}$ to $4.5\cdot 10^{9}$ y)

{ geochemical measurement:

Old mineral (containing Se) ⇒ extraction of Kr ⇒ checking of isotope composition ⇒ excess of ^{82}Kr ⇒ $T_{1/2}$ (2β) }

$T_{1/2} = (0.8 \pm 0.15) \cdot 10^{20}$ y

(average value for samples with age
$t < 0.1 \cdot 10^9$ y

$T_{1/2} = (1.32 \pm 0.06) \cdot 10^{20}$ y

(average value for samples with age
$0.17 \cdot 10^9 < t < 0.33 \cdot 10^9$ y)

$T_{1/2} = (1.28 \pm 0.07) \cdot 10^{20}$ y

(average value for samples with age
$1 \cdot 10^9 < t < 2 \cdot 10^9$ y)

Conclusion: Rate of decay now is ~ 50% - 60% higher than in the past (≥ 3σ effect!).

2. ^{130}Te.

$^{130}Te \to {}^{130}Xe + 2e^- + 2\nu$

There are geochemical experiments only:

"Young" samples ($t \approx 2.8 \cdot 10^7 - 10^8$ y) - **$T_{1/2}^{2\nu} \cong 0.8 \cdot 10^{21}$ y**

"Old" samples ($t \geq 10^9$ y) - **$T_{1/2}^{2\nu} \approx 2.7 \cdot 10^{21}$ y**

(Statistically more than 10σ effect; T. Bernatowicz et al., Phys.Rev. C47 (1993) 806 **$T_{1/2}^{2\nu} = (2.7\pm0.1)\cdot10^{21}$ y**)

Average values:

$T_{1/2} = (0.81 \pm 0.05)\cdot10^{21}$ y (average value for samples with age $t < 10^8$ y)

$T_{1/2} = (1.71 \pm 0.04)\cdot10^{21}$ y (average value for samples with age $1\cdot10^9 < t < 2.5\cdot10^9$ y)

Prediction from direct experiment with ^{82}Se:

$T_{1/2}\,(^{82}\mathrm{Se}) = (0.9 \pm 0.1)\cdot10^{20}$ y

and using ratio **$T_{1/2}\,(^{130}\mathrm{Te})/T_{1/2}\,(^{82}\mathrm{Se}) = 9.9 \pm 0.6$** from geochemical measurements with minerals contain both Te and Se “present” value of half-life is ⇒

$T_{1/2}\,(^{130}\mathrm{Te}) = (0.9 \pm 0.15)\cdot10^{21}$ y

Very soon this value will be checked by direct **NEMO-3** and **CUORICHINO** experiments (some indication was obtained in Mibeta experiment - **$T_{1/2}\,(^{130}\mathrm{Te}) = [0.61\pm 0.14\,^{+0.24}_{-0.35}]\cdot10^{21}$ y)**

<u>Conclusion:</u> Rate of decay now is ~ 50% - 90% higher than in the past (> 3σ effect!).

3. ^{96}Zr. $^{96}Zr \rightarrow {}^{96}Mo + 2e^{-} + 2\nu$

"Present" value - $T_{1/2} = (2.1 \pm 0.3)\cdot 10^{19}$ y

(**NEMO2 + NEMO3** result)

"Past" value - $T_{1/2} = (3.9 \pm 0.9)\cdot 10^{19}$ y
(geochemical experiment, $t_{min} = 1.7\cdot 10^{9}$ y; A. Kawashima et al., Phys.Rev. C47 (1993) R2452)

Conclusion: "present value is ~ 1.5-2 times smaller than in the "past"

(~ 2σ effect).

But recently (M. Wieser and J. De Laeter Phys.Rev. C64 (2001) 024308) new geochemical result ($t_{min} = 1.8\cdot 10^{9}$ y) was published:

$T_{1/2} = (0.9 \pm 0.3)\cdot 10^{19}$ y **(???)**

No any conclusion can be done now for ^{96}Zr

^{130}Te and ^{82}Se ⇒ Rate of 2β-decay now is ~ 50% - 90% higher than in the past (> 3σ effect!).

If the effect connected with time variation of G_F then **$\Delta G_F/G_F \approx -0.1\text{-}0.2$** and tacking into account possible errors **$\Delta G_F/G_F \approx -(0.05\text{-}0.3)$.**

$$G_F = 1/\sqrt{2}\cdot\eta^2 \qquad (m_e \sim \eta)$$

were η is the vacuum expectation value of Higgs field.

It means that if G_F is increasing with time η is decreasing

$\{$ ~ (5 - 30)% of G_F ⇒ ~ (2-15)% of η $\}$

If it is truth, it will have very serious consequences for physics and astrophysics. But, exactly because of this, one has to confirm (or refute) the fact of these discrepancies.

HOW TO DO THIS?

⇓

IV. FUTURE EXPERIMENTS

1. To do new precision measurements of "present" values for **$2\beta(2\nu)$** half- lives in ^{82}Se, ^{96}Zr and ^{130}Te (with accuracy on the level ~ 5-10%). - **NEMO, CUORICINO**

2. To do precision measurements of "past" values (geochemical experiments) for **$2\beta(2\nu)$** half-lives in ^{82}Se, ^{96}Zr and ^{130}Te (with accuracy on the level ~ 3%-10%);
   to do the measurements with different age samples (from 10^7 to $4.5 \cdot 10^9$ y).

3. To investigate possibility to do new geochemical experiments with **^{100}Mo**, ^{116}Cd, ^{124}Sn, ^{110}Pd and ^{76}Ge.

^{100}Mo: **1**) maximum 2β-decay rate;
2) high concentration in natural Mo (9.6%);
3) ^{100}Ru (not gas!) as final nucleus.

Accuracy of "present" half-life value of **^{100}Mo** is ~ 7% and it can be improved up to ~ 2-3% by **NEMO-3**.

V. CONCLUSION

1. There are discrepancies:
   a) between results of direct and geochemical 2β-decay experiments in ^{82}Se;
   b) between results with "young" and "old" minerals for ^{82}Se;
   c) between results with «young» and «old» minerals for ^{130}Te.

2. All these discrepancies could be explained by time variation of G_F ?!

3. I propose to check these discrepancies by new direct and geochemical experiments.

Washington University (St. Louis, Missouri), 2002

Start to work with **^{130}Te** again. Main goal is:

To solve the " tellurium-130 problem".

There are two different results for half-life from geochemical experiments:

~ (2.5-2.7)$\cdot 10^{21}$ y and **~ 0.8$\cdot 10^{21}$ y**

Usually for old minerals (> 10^{9} y) we have the first result and for young minerals (~ 10^{8} y) we have the second value.

Two explanations have been suggested from research groups advocating either "low" or "high" values for the **^{130}Te** half-life:

1) low age proponents proposed that , since tellurides are "soft" low-temperature minerals, they may not retain Xe well, therefore the shorter half-life might provide the correct value;
2) High age proponents suggested that during telluride formation they inherited and trapped some mono-isotopic ^{130}Xe from ores of a previous generation, explaining the "low" measured **^{130}Te** half-life.

Preliminary conclusion:

"We have found that neither Xe loss or Xe inheritance are responsible for observed diversity of measured ^{130}Te half-life. There is an intriguing qualitative trend: the older the tellurium mineral, the higher the measured half-life seems to be."