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A WORKING HYPOTHESIS ON THE MUON-DECAY TIME SHORTENING AND TIME

The Earth's atmosphere is showered with cosmic rays that originate from interstellar space. When cosmic rays collide with the Earth's atmosphere, they decay into Muons. These Muons further decay, with several different decay modes, over accurately measured time (out to six to eight significant figures). Muons can be represented as clocks, which can run fast or slow.

Here I have speculated that the duration of Muon decay measured in experiments in 1946—2017 years, which should be a constant, appears to shorten gradually, perhaps irregularly (including pauses), from very roughly 2.330 s (1946) to very roughly 2.202 s (1962—1963). There are questions concerning the most recent measurements, and more accurate experimental data is required to confirm or view with doubt a trend for the gradual shortening of Muon decay time. Namely, from 2007.0 to 2009.5 the more precise Muon decay time measurements exhibit a decrease in apparent Muon decay time of very approximately 13 ps per year. Although this numerical trend is not statistically significant, certainly the apparent decrease in Muon decay time cannot be absolutely ruled out according to a review of the presented data.

Speculation about the cause of the apparent shortening of Muon-decay time suggests that it is tied to the possible variation of the speed of time (clocks running fast or slow) in our Universe. The working hypothesis, to inspire the research of others, is that the intrinsic Muon decay time is not decreasing slightly as measured on its intrinsic clock, but its apparent decay time is decreasing slightly as measured on clocks associated with our Earth and/or our Universe; clocks that are running very slightly fast and slowing down. Several published studies of time variability in our Universe are analyzed. A Proposition that some complex processes or sub systems such as Muon decay are "marching" to their own intrinsic, fixed, "time" or timeframe, which is independent of the flow of "time" in our Universe, is proposed and several published research papers are cited to support the Proposition. Ramifications of the possible change in the speed of time to various scientific fields are mentioned.

Keywords: *Muon, Muon decay time, speed of time, high-frequency gravitational waves, relic gravitational waves, dark matter, dark energy, early universe, big bang, big rollout.*

INTRODUCTION AND REVIEW OF APPARENT MUON DECAY TIME

The Earth's atmosphere is showered with cosmic rays that originate from interstellar space. When cosmic rays collide with the Earth's atmosphere, they decay into Muons. These Muons further decay, with several different decay modes, over accurately measured time (out to six to eight significant figures), and almost always produce at least three particles, an electron and two neutrinos. Muons can be represented as clocks, which can run fast or slow. Here I speculate that the duration of Muon decay, which should be a constant, **appears** to shorten gradually, perhaps irregularly (including pauses — when the speed of time remains constant for a while), from 1946 to 2017 from very roughly 2.330 microseconds

(1946) to very roughly 2.202 microseconds (1962—1963) to very roughly 2.078 microseconds (2016—2017)[1]. There are questions concerning these most recent measurements and more *accurate* experimental data is required to confirm or view with doubt a trend to the gradual shortening of Muon decay time. From 2007.0 to 2009.5 the more precise Muon decay time measurements exhibit a decrease in **apparent** Muon decay time of very approximately *13 ps per year*. Although found not to be a statistically significant well-defined numerical trend, certainly the **apparent** decrease in Muon decay time cannot be absolutely ruled out as a working hypothesis[2] according to a review of the presented data in theTable[3] and Fig. 1. Suffice it to say that the existence of such a trend would be an extremely interesting result and is a worthy speculation.

As Clive Woods suggests (email November 18, 2018) "Regarding the assertion that the data **do not preclude a trend to shorter decay times**, the recent results if verified would indicate a reduction in the decay time around 2015. However, let's assume that we should drop the 1946 measurement (very imprecise and **not** included in Fig. 1a), the two most recent measurements (clear possibility of systematic error and are also **not** included in Fig. 1a), and also the two 2015 measurements (very imprecise for such recent work). Although there is apparently a drop from 1962 to 1973, the error bars on the 1960s measurements are large enough that the results from 1973 to 2013 aren't too far away (around 1.5 standard errors) and it is **clearly plausible** (that the data **do not preclude a trend to shorter decay times)**...*"* Woods also suggests that the elimination of such outliers would mask the presence of a trend. In fine, Woods states: "*I can neither rule out a* working hypothesis that the decay time has declined*, nor rule out a working hypothesis that the decay time has remained constant*." (Bold type and italics added for emphasis.)

Speculation about the **cause** of the apparent shortening of Muon-decay time, under the former working hypothesis, suggests that it is tied to the possible variation of the speed of time (clocks running fast or slow) on or near our Earth. The working hypothesis, to inspire the research of others, is that the **intrinsic** Muon decay time is **not** decreasing slightly as measured on its intrinsic clock, but its **apparent** decay time is decreasing slightly as measured on clocks associated with our Earth and/or our Universe; clocks that are running very slightly fast and slowing down. The novel concept is that the time dimension, like space dimensions, can have a rate of progress or "speed" that can change. That time can accelerate, deceleration or even pause and just proceed at uniform, constant speed for a while. Several published studies of time variability in our Universe are analyzed. A Proposition that some complex processes or sub systems such as Muon decay are "marching" to their own intrinsic, fixed "time" or timeframe, which is independent of the flow of "time" in our Universe is proposed and several published research papers are cited to support the Proposition. Ramifications of the possible change in the speed of time to various scientific fields are mentioned. Of special interest is the effect of the speed of time on the rate of expansion of our

[1] (**Ed**. – The Reviewer 2 noted that these measurements (2016—2017) should be excluded from consideration because they contain a systematic error. The reviewer also added: "Contrary to the author claim there are data in the literature about variance of radioactive decay of different isotopes with 1σ accuracy up to 5 digits for the span of many years, see e.g. Table of https://doi.org/10.1016/j.apradiso.2017.09.002. No signs of change were detected. Author is absolutely right that muon lifetime measurements represent the best tool to probe possible weak interaction changes (in the wider context of the fundamental constants change with time), but the bottom line of the collected evidence so far is that no such changes have been found yet.")

[2] A working hypothesis is defined (Wikipedia) as a hypothesis that is provisionally accepted as a basis for further research in the hope that a tenable theory will be produced, even if the hypothesis ultimately fails or is significantly modified (Isaac Newton's Principia Mathematica, as significantly modified by Einstein, is an example). It is essentially an encouragement for further research and analyses.

[3] (**Ed**. – The Reviewer 3 noted as follows: "I included 10 measurements presented in the Table (from 1963 to 2009 and in 2017) to determine a trend and obtained that σ (–0.659) and $\chi^2[8] = 383.795185679$; so, **there is no statistically significant linear trend in them, even on 1σ level**. When I excluded the measurement of 2017 ("outlier data point"), the scale is better, but σ(-0.872) and $\chi^2[8] = 270.805982697$) testify that **this trend isn't statistically significant too**. Of course, there is a common question to the different determination of measurement's accuracy; by the way as the interesting fact, **if these accuracies not to take into account, the trend exists but it's not statistically significant too.")**

Universe, dark matter and dark energy, possible generation of the *Oh-My-God* particles as well as theories about the beginning of our Universe. For example, a rollout of spacetime from vanishingly small space dimensions (for example a Planck length) and at time "zero" (for example Planck time) approaching infinitely fast speed of time, to today's values and is speculated even if the Proposition is unproven.

In Fig. 1a, a review of the measurements (blue dots) appear to exhibit a trend to longer apparent Muon decay time as the years go by. Figure 1b shows the experimental data collection from 1963 to 2017 and the data point's error. The Muon decay time cited in [7] by Tischchenko for 2013 is actually a copy of the Webber/MuLan [6] 2009.5 experiment. Likewise the data points (red dots) at the top of Fig. 1b are most likely copies of a prior Muon-decay time experiment. The negligible change in apparent Muon-decay time change (these data points suggest) is either NOT from independent data obtained from separate experiments or the result of a pause in the speed of time change during which apparent Muon-decay time remains constant for a while. These questionable data points (red dots) should not be included in any comprehensive curve fit.

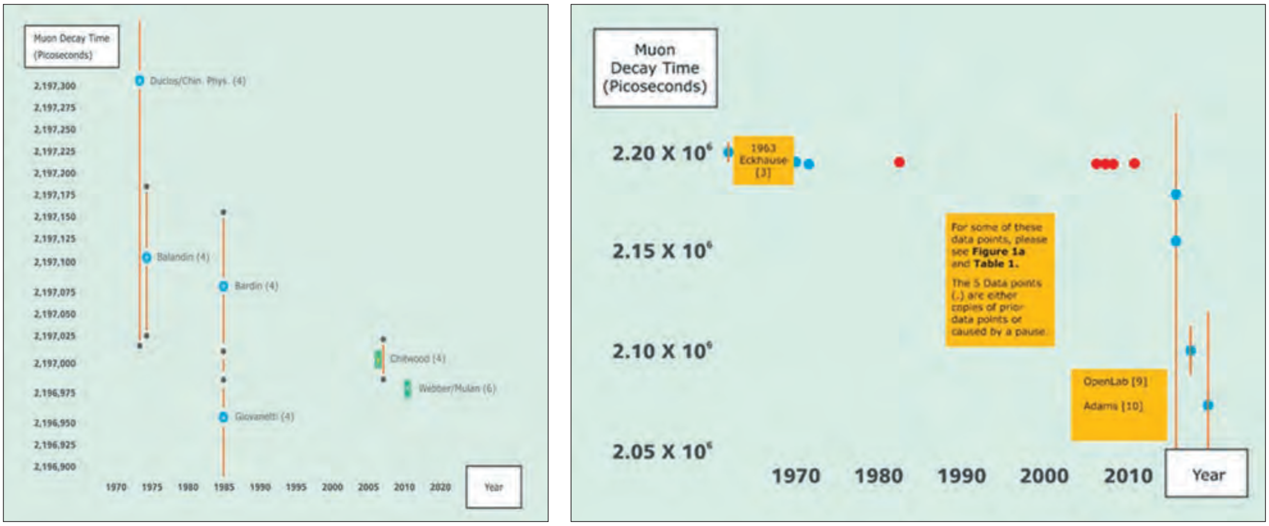
As remarked by a reviewer 2, the data from [9], 2016 are for the Muons in a plastic scintillator: "To measure the Muon's lifetime, we are interested in only those Muons that enter, slow, stop and then decay inside the plastic scintillator", and authors of [9] claim: "The value that is obtained is probably slightly underestimated since the frame window taken into examination had up to 7 μs delay. This value is, however, in agreement with the result that you should get which stays between the theoretical value of **2.2 μs for positive muons**, which is equal to

Review of Length of Apparent Muon Decay Time Versus Time

Date of Measurement	Apparent Muon Decay Time, ps	Estimated Error, ps	Muons at Rest or in high-speed Cosmic-ray generated Motion?	Reference
1946.0	2,330,000	±150,000	At Rest	Conversi, Pancini, Piccioni [1]
1962.0	2,203,000	±4,000	At Rest	Lindy [2]
1963.0	2,202,000	±3,000	At Rest	Eckhause, et al. [3]
1973.0	2,197,300	±300	At Rest	Duclos/ Chin. Phys. [4]
1974.0	2,197,110	±80	At Rest	Balandin/ Chin. Phys. [4]
1984.0	2,196,950	±60	At Rest	Giovanetti/Chin. Phys. [4]
1984.0	2,197,078	±73	At Rest	Bardin/Chin. Phys. [4]
2007.0	2,197,013	±21	At Rest	Chitwood/Chin. Phys. [4]
2008.0	2,197,083	±32	At Rest	Barczyk/Chin. Phys. [4]
2008.5	2,197,030	±40	At Rest	Coan & Ye [5]
2009.5	2,196,980.3	±2.2	At Rest	Webber/MuLan [6]
2013.0	2,196,980.3	±2	At Rest; a copy of 2009.5 measurement	Tischchenko [7]
2015.0	2,110,000	±70,000	Fast, Cosmic Ray	Barazandeh [8]
2015.0	2,165,000	±403,000	Fast, Cosmic Ray	Barazandeh [8]
2016.0	2,078,000	±11,000	At Rest	Physics OpenLab [9]
2017.0	2,080,000	± 11,000	At Rest	Adams [10]

Note 1. Since the Muons are not at rest these two measurements will be neglected. However, their decay times are longer than the recent 2016 and 2017 time measurements due to time dilation and tend to validate these two recent measurements. Moving clocks run slow due to time dilation and the Muon decays more slowly as measured by an earth-bound clock. Therefore Muon decay time observed in a ground frame of reference is longer just as the 2016 and 2017 data show. Specifically, the fast Muon decay times: 2,110,000 ps and 2,165,000 ps should be and are longer than the At Rest decay times 2,078,000 ps and 2,080,000 ps (this latter value selected from the three measurements presented in [10]). A picosecond, ps, is a trillionth of a second, or 0.000,000,000,001 seconds. Another recent measure in 2016 by Noah Scandrette, although not in a journal, was 2,150,000 ± 40,000 ps (https://ueap.sfsu.edu/sites/default/files/assets/writing_awards/Measurement%20of%20Muon%20Lifetime.pdf Page 1) and was between the Webber/MuLan [6] 2009.5 and Physics OpenLab [9] (on Page 7), 2016 measurements.

Note 2. Most recently, L. R. P. Sanchez and F. Izraelevitch measured a very short apparent Muon decay time of 1,800,000 ps without published error, which should be carefully scrutinized: IOP Conf. Series: *Journal of Physics: Conf. Series*, 866 (2017) 012011.



a *b*

Fig. 1. *a* — Review of **apparent** Muon decay time measurements and error from 1973 to 2009 from Table on decay time review, picoseconds, from 1960 to 2017. In part adapted from a referee's diagram[2]; *b* — apparent Muon decay time review, picoseconds, from 1960 to 2017. In part adapted from a referee's diagram[2]

the value measured in empty space, and the value of **2.04 μs for negative muons**, which are affected by the interactions with the nuclei of the scintillator material" (emphasis by the authors of [9]). For this reason data from [9] will be excluded from further detailed analysis on a provisional basis. As Clive Woods notes (email November 18, 2018) "I can understand that your graph (Fig. 1a) omits some measurements only recently discovered. Also it's not necessary *to include any kind of curve fitting to the data.*" (Italics and bold type added for emphasis.)

It is emphasized again that only a **possible data trend** has been observed, but it certainly **does not absolutely rule out** a decrease in apparent Muon decay time over the years. From the more comprehensive Table, which includes estimated errors, it appears that there is a decrease in very approximate apparent Muon decay time from 1946 [1] (2,330,000 ± 150,000 ps) to 2017 [10] (2,080,000 ± 11,000 ps) or –250,000 ps. The *errors are quite large* so that over the 2017 – 1946 = 71 years the apparent Muon decay time change, if but one extreme error outlier (e.g., a standard deviation) on the longer time side to the other on the shorter time side taken to **minimize** the difference would be (2,080,000 + 11,000 = 2,091,000) – (2,330,000 – 150,000 = 2,180,000) = –89,000 ps difference or, over the 71 years, about –1,250 ps per year. This value is still very approximate, especially considering the equipment errors such as found in the data presented in [9]. For this reason, let us consider in detailed numerical calculation **only** the more accurate MuLan collaboration values from the Table. The combined results (circa 2009—2010 or 2009.5) due to MuLan give apparent Muon decay lifetime = 2,196,980.3 (±2.2) ps, which is more than a dozen times as precise as previous experimental measurements [6]. The previous 2007 determination given in Olive/Chin. Phys. [4] by Chitwood (2007) of 2,197,013 (±21) ps and depicted in Fig. 2 of [6], and in Fig. 1a as well as Table 1, show a decay time shortening, with respect to the MuLan value (green highlighted in Fig. 1a), of **–33 ± 23 ps** over about 2.5 years or **13 ps per year**, which is a *more precise* calculation. (The variation or decrease in decay time is quite small: (33 ps/2.5 yrs)/ 3.15×10^{19} ps per yr = 4.2×10^{-19} ps per ps). However, this estimate is only over the very limited 2007—2009.5 time period and as indicated by Leslie Sage (e-mail March 28, 2018 concerning an early draft of this paper) it "...is less than 2sigma (95 % probability)...", and therefore this numerical estimate is not statistically significant. As recognized by Clive Woods, there is little justification, however, to accomplish a more rigorous statistical analysis over the 1946 to 2017 time frame until more accurate data are obtained such as by a greatly improved atomic clock discussed herein in the Section on THE NEXT STEPS. On the other hand, these arithmetic examples and examination of the Muon decay lifetimes in the Table and Fig. 1a provide observational evidence that there **is a** trend *of shorter apparent Muon decay times* as the years pass by. To be on the conservative side therefore, it is fair to suggest the *discovery* is that **these data certainly do not rule out that there is a continuing decrease in the apparent Muon decay time at least during the 2007 to 2009.5 time frame and probably during the 1946 to 2017 time frame**. Therefore it is also fair to speculate on what the consequences or *application* of such a trend would be if the trend actually exists[4].

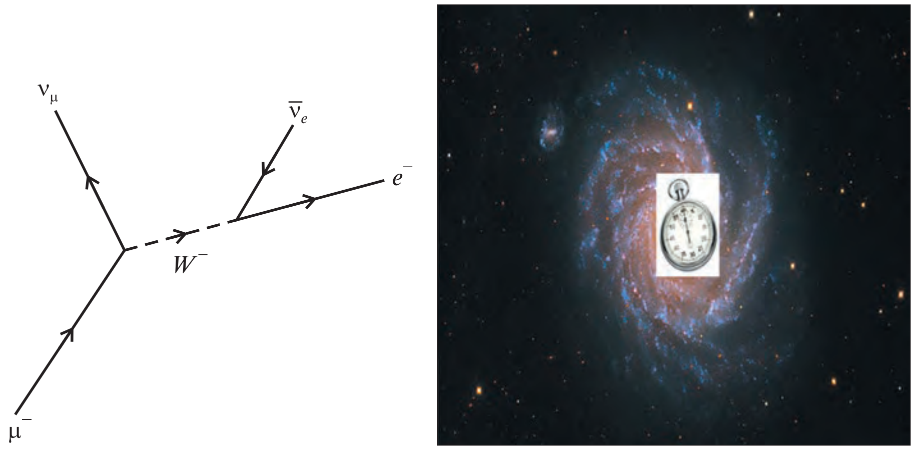
SPECULATION ON CONSEQUENCES OF THE POSSIBLE CHANGE IN APPARENT MUON-DECAY TIME

Prior to selecting Muon-decay time for analyses, a search was conducted for both chemical and nuclear complex, transient processes, such as electro-weak nuclear reactions, that had measurable, assumed *constant* durations. The motivation for this search was to find a way to confirm my earlier speculation or concept concerning the decrease in the speed of time since our early Universe; that is to find a "yard stick" to gauge the speed of time. The search was to find very precise data concerning such a yard stick or transient process, to six to eight significant figures, taken over many decades. Muon decay was found to be a transient process or quantum mechanical subsystem, whose decay time has been accurately measured over several decades to a precision of six to eight or more significant figures and was selected for review and analyses. As footnoted in the Table, Muon decay time is longer, when Muons move rapidly in the upper atmosphere after their birth due to cosmic ray collision with the atmosphere than when at rest, due to time dilation (time dilation effects [Chapter 11, Eq. (11-8) of 8]). In explaining this effect, a **Muon is considered to be a clock**, whose time can move at a **different speed** than an earthbound clock. A similar concept is applied herein, but the speed of time **in an earthbound clock** is considered to move at different speeds as the years pass by. The working hypothesis is **not** that the intrinsic Muon decay time (or any other complex electro-weak decay time) is decreasing with time; specifically, not the 4.2×10^{-19} ps per ps, **rather the working hypothesis is that the intrinsic Muon decay time <u>is constant or fixed</u>, but the clocks on Earth are slowing down!** As opposed to Muon decay time, the speed of time effect is quite subtle: since the "big bang" the time may have "changed" **only** (33 ps/2.5 yrs) $\times$ 1.38 $\times$ 10^{10} yrs/1.0 $\times$ $\times$ 10^{12} ps per sec = **0.18 seconds**! Of course it is suggested by the author that this speed change is just the tail of a **series of significant time-speed changes** over the billions of years since the early Universe. The published analyses of Vaas, Beckwith**,** Fontana, Karimov, Mars, Bars, Senovilla, and Vera will be cited in the following paragraphs to support various aspects of the author's hypothesis. What is new is the present author's *discovery* that the intrinsically constant Muon decay lifetime, which is **apparently** decreasing, may be a quantitative "yard stick" that can be utilized to establish the local speed of time on the Earth and/or Universe and to inspire the research of others. A brief talk and single Poster were presented on this discovery and its applications at the Annual Meeting of the *American Association for the Advance-ment of Science* in Austin, Texas on February 18, 2018. Please see the Appendix.

THE TIME CONCEPT OF DIFFERENT PHYSICAL SYSTEMS

Since the dawn of civilization on "Earth time" has been an essential concern of humanity in general and Physical Science in particular, especially, Physics,

[4] (Ed. – Reviewer 2 noted: "Using the linear trend model against constant lifetime model for the data of [1—6] we conclude that both by finite sample corrected Akaike Information Criterion and by Bayesian Information Criterion constant lifetime model is preferable over linear trend model: 140.79 vs. 144.219 AICc and 139.68 vs. 141.13 BIC. So that statistically speaking **there is no trend in the data presented in the paper (as we have discussed, data from [10] should be excluded by the same cause as data from [9])...** We think that the paper can be published only in the case if the author formulate clearly and unequivocally that the data do not show any trend but suggests its possible existence. At the same time, the experimental data do not completely exclude the existence of a trend, which may or may not be confirmed when analyzing future experiments. It is possible to say, additionally, that existence of such a trend would be an extremely interesting result and is worth to speculate about.")



A B

Fig. 2. Subsystem A of Muon decay (having its own clock) and Macrosystem B (having "macro time") for example a galaxy and its rotational rate (like the hands on a clock, the arms of a galaxy, viewed at a several billion year earlier time, would be appear to be rotating faster if time is moving faster at these past times)

Chemistry, Engineering and Astronomy. Poincare and Einstein both proposed a revolutionary concept that time need not move uniformly and regularly as the rate of movement of a pendulum, but that its "rate" could appear to change based upon relative speed and acceleration of clocks. However the concept proposed here is quite unlike Einstein's special and general relativity theories, which involve speeding and accelerating frames of reference, respectfully — speeding and/or accelerating reference frames are not involved or necessary in my concept. As will be discussed, Muon decay time may be a measurement means to determine the speed of time (clocks running fast or slow) in our Universe. However, my speculation concerning the variation of the speed of time as our Universe progresses is **not** contingent upon any particular proposed measure-ment means.

Special consideration is given to Rűdiger Vaas' statement: "The particle physics arrow of time: the decay of certain particles, the neutral K mesons (kaons) and B Mesons and their anti-particle (and *Muons*), lead implicitly to the conclusion that there is an asymmetry of time because decay breaks other symmetries" [12]. Furthermore, according to Andrew W. Beckwith [13]: "However, the issue Dr. Baker has raised is suggestive and should be thoroughly analyzed. The author (Beckwith) finds that aside from inevitable scaling arguments, that the Muons are still a sub system, within a larger general system, i.e. the adage of Schrödinger who postulated that quantum sub systems, of a macrosystem definitely exhibit *quantum mechanical time dependent behavior*. Equation (51) is not quantum mechanical, but it is a sub system, and so the same rule by Schrödinger, as to **sub systems exhibiting definite time dependence**, may be applicable here. I.e. **think in terms of time variance**." (Section XVII of [13], italics and bold type added for emphasis in these quotes.) As suggested in an email by Giorgio Fontana (October 31, 2017): "Muon decay time can be considered to be an **absolute time ruler** and separate from the timeframe as measured in our Universe" [14]. And Alexander Karimov suggests "... time flow of an individual object is a real physical value ... time for the single object (subsystem) and time for the whole system (macrosystem) can be different" [15] — italics and bold type added for emphasis. There may of course, be many possible causes for the Muon decay time shortening if indeed that shortening exists, which the author believes it obviously does. The speculative cause that is suggested by the foregoing quotes is the: **Proposition that some complex processes or sub systems are "marching" to their own intrinsic "time" or timeframe that is independent of the flow of "time" in our Universe.**

By "complex" is meant those transient processes or subsystems, such as electro-weak decay, that involve one or more quantum mechanical sub-reactions, some well understood and some not well understood, that in total comprise a complete, possibly multiplestep process or quantum mechanical subsystem *having a well-defined beginning and end*. But even if the Proposition is conceded to be correct, then should not the very clocks that are utilized to measure Muon decay lifetimes also change speed and operate on the same intrinsic timeframe as Muon decay? **No**; unlike the *intrinsic or complex* decay time of a Muon, one second is defined as the time that elapses during transition between two energy levels of the cesium 133 atom. Also Muon decay time is unlike the period of a pendulum, which depends on its length and the strength of gravity (essentially, the change between potential and kinetic energy levels). Such cesium-atom energy level changes and pendulum swings, essentially timed energy-level changes (somewhat like a rock falling a given distance as a time interval definition), are the "stopwatches" of our Universe and, **since they are not "complex"** and there is no an asymmetry of time can be utilized to measure the apparent duration of Muon decay and thereby possibly determine the "speed of time" in our Universe.

The truth of the Proposition, as symbolized in Fig. 2, depends upon the measured disparity (e.g., the Table) between *complex* processes, which should always have the *same duration* in their timeframe, for example Muon decay **A,** and the time duration as measured in our Universe's timeframe **B** (termed macro-time), for example by cesium atomic clocks and pendulums (stopwatch shown in **B)**. **It is speculated therefore, that the slowdown of time in our Universe, or specifically local to the Earth, can be measured by Muon-decay time acting as an "absolute time ruler or yard stick."** The Proposition could manifest itself in all the electro-weak processes including radioactive decay and stability of atomic nuclei if and only if they are *complex processes*. Other than Muon decay, other such evidence concerning electro-weak, complex processes should be sought. Atomic clocks may be able to very accurately measure different transient, complex processes (subsystems), both on Earth and in space, that could improve this estimate of the reduction (in general, the variation) of the speed of time on Earth and possibly add data in support of the **Proposition** or falsify it**!**

In order for a Proposition to be robust, there needs to be a means to falsify it. In the case of the Proposition put forth in this discussion, there are at least three such means: First, other Muon decay time measurements could be newly taken, or found from past experiments, that do not exhibit the tendency to decrease or gradually change with the years or, for that matter, other similar independent transient, *complex* subsystems that do not show an annual decrease. Of course, there is no *a priori* reason to expect that a pause in the speed of time variation would not occur—that is, the speed of time and Muon decay time could remain constant for a while. Second, a systematic error involved in the Muon-decay time's measurement equipment is discovered that cause times to appear to decrease over the years without actual decay time change. Third, a theoretical repudiation of the Proposition or subsystem concept that some processes or subsystems are "marching" to their own intrinsic "time" or timeframe, which is *independent* of the flow of "time" in our Universe, as well as an **alternative**, replacement Proposition, Theory or finding to explain the Muon decay time annual decrease. As one example of an alternative theory, consider the suggestion of Christian Corda, Giorgio Fontana and Gloria Garcia Cuadrado [16 p. 1055, 17]) who reports: "... reality is described with four space-like coordinates and an infinite number of 'local' time variables."[5]

[5] (Ed. – The Reviewer 2 noted: "Abstracting from the time as philosophical category, in the framework of relativity time as a measurable quantity is the clock readings at rest in a specialized reference frame. Relativistic effect of time dilation appears when we compare in two different reference frames (RFs) time intervals between two space-time events. It is not that time "marching" differently in these two RFs. From physical point of view the time is not an ontological object possessing any properties, such as "marching" faster or slower. It is not that time dictates to clock as they should "tick", but clocks readings define properties of time. Further complications arise if we need to compare two non-identical clocks. In this case the time defined by the first clock can "march" differently from the time of the second one. But this is due to the difference of physical subsystems, chosen as the clocks, but not due to the properties of time itself as ontological object. From the above we can say that from physical point of view the change of muon decay time in laboratory RF, whether it is real, should be related to some hypothetical dependence of electroweak interactions on laboratory time. The statement that it can be explained as different time "marching" in different physical subsystems is a simple tautology. At the same time, the review part of the paper concerning time concept of different physical systems is of some interest in a methodological or philosophical sense.")

SPEED OF TIME IN OUR UNIVERSE MAY BE CHANGING

Of course time, like the space dimensions: east-west, north-south and up-down, is a direction and directions do not have "speed" so we are discussing **speed of time as a rate of progression of time along the dimension of time** in the space-time continuum of our Universe. Therefore, time can have a speed, with clocks running fast or slow, just like movement in the other three space-time dimensions exhibit a speed. It is speculated that the speed of the "flow of time" in our Universe might change (accelerate or decelerate or occasionally not change or pause) over the years, perhaps decelerating from a very high speed in the early universe, as discussed in Appendix B of [13] and Chapter 8 of [11], especially Exercise 8.2. There is ongoing debate over the meaning of time and the foregoing analyses and notions are open to considerable debate as in references [12], [19], [20] and, especially, in Carlo Rovelli's Book [21].

According to Julian Barbour [22, 23]: "Clocks are useless if they do not march in step for otherwise we cannot keep appointments. Therefore, it is not a clock that we must define, but clocks and the correlations between them as expressed in the marching-in-step criterion." But when they do not march in step that is where time as a "duration" becomes interesting. Again according Barbour "Occam's razor tells us to avoid redundant elements. All we need are differences. Indeed, the passage of time is always marked by difference ..." Suppose, as discussed in [footnote 5, p. 54 of 18], you are a trainer of a *mile runner* who you just measured as doing a four-minute mile. Another trainer says that cannot be correct "Your runner could not have improved that much, your stopwatch must be running slow since we all measured that he only ran a five-minute mile last year." Well, you argue "No, he has not improved at all, he ran at the same *intrinsic* speed as last year. You all had stopwatches that were running fast and miss-measured my runner's speed last year!" In this case, last year's stopwatches were moving (4 minutes – 5 minutes) per year = –1 minutes/year or, equivalently, 60 seconds per minute/3.154×10^7 seconds per year = -1.9×10^{-6} second per second times slower than today's stopwatches. The number is negative, since the speed of time is decreasing. If the runner's intrinsic speed remains unchanged or fixed, but the stopwatches each past year run faster and faster, e.g., faster in 2017 (measured 5-minute mile), than in 2018 (measured 4-minute mile), even faster in 2016 (measured 6-minute mile) than 2017, even much faster in 2015 (measured 7-minute mile) than 2016, etc. (and the stopwatches are therefore, slowing down as time goes by). Imaginably, there will be a continuing lengthening of the measurement of the runner's time during the previous years and conversely the runner's time to run a mile reduces as the years role by[6]. Such is the analogy of the intrinsic, essentially fixed, mile-runner time to the intrinsic Muon unchanging or fixed decay time. For example, in 2017 (measured 2.080 microseconds decay time), in 1963 (measured 2.202 microseconds decay time), in 1946 (measured 2.330 microseconds decay time) and so on. Analogous to and the trainers' stopwatches' measured time on the track or the atomic-clocks' measured time on the Earth in both cases measured time, or in the latter case time itself, is slowing down. (If the speed of time in our Universe approaches zero at the "end of time", then the apparent Muon decay time there will approach zero; analogously, the mile runner completes his run in "no time at all." **The trainer's Stopwatch second hand hardly moves,** but as will be mentioned the mile might lengthen towards infinity near the end of time! Also the mile might shrink in the past near the beginning of time.) Time in our Universe commences at near "zero", or possibly Planck time, and then proceeds to the end of time many billions of years later. During this period black holes may develop and the flow of "time" for them is not known. For example, as predicted by Einstein's general theory of relativity, time would slow tremendously near the edge of a black hole, in fact time may approach a standstill similar to the "end of time" of our Universe. As will be discussed in the section on "**WHAT ARE THE NEXT STEPS?"** perhaps the detection of high-frequency gravitational waves (HFGWs) from black holes and black-hole mergers would provide the answer to this quandary.

[6] Of course, the analogy to a mile runner breaks down when compared to Muon decay. Both are complex processes or sub systems, but one would need many identical replicant mile runners, a new one of them to run each year, for an exact analogy.

The present author had previously conjectured that time moved very fast in our early Universe and that it might still be slowing down from that maximum speed [Chapter 8, especially Exercise 8.2 of 11 and Appendix B of 13]. Alan H. Guth at Cornell University proposed the theory that our Universe was "inflating" the idea is "... that the nascent universe passed through a phase of exponential expansion soon after the Big Bang, driven by a positive vacuum energy density." And that in a remarkably short time of 10^{-34} seconds the Universe became the size of a marble [24]. Working the arithmetic [7] indicated that the material of the Universe, if containing information, had to be moving on average over 10^{23} times the speed of light or maximum speed of information, counter to the contention by Einstein, as to the constancy of the speed of light in all frames of reference (special relativity). That is, all physical laws are contended to be the same in these frames of reference at any given time. Of course, nothing prevents the universe itself or various "effects" from expanding or moving faster than light. For example, a lighthouse beacon's projected light spot can at a great distance "move" in excess of light speed. But, assuming the "material" of our early Universe contains information, even expanding like the dots on a bellowing balloon, which has information on its "edge", cannot "take" or "move" information from one "dot" to another "dot" position faster than light speed. As already noted, it is speculated that time itself may be running at different speeds in our early Universe and that the speed limit of light or information might not actually be violated in our early Universe. That is, if time were running really fast in our early Universe, then the speed of light measured there would **not** be over the "speed limit" of information.

It may be that the speed of time is slowing from that speculated early very high rate. Similar to Guth's theory there is no observational evidence for such a high speed of time, simply an interesting conjecture. In particular, the field responsible for Guth's cosmic inflation has not been discovered. ***By Occam's razor the concept of changing the speed of time is SIMPLER to visualize (we all are familiar with our watches running fast or slow) than Guth's "positive vacuum energy density" and therefore I believe it to be preferable.*** In addition, it is speculated that the variations in the speed of recession and/or rotational rate of galaxies as well as the Hubble parameter may result in whole or in part on variation of the speed of time. In this very same regard, Jose M. M. Senovilla, of the University of the Basque Country, Spain, in 2008 theorized that the expansion of our Universe is an "*illusion*" and actually is the result of the *higher speed of time* during the period when the light left the stellar structures in the past: "... we are fooled into thinking that the expansion of the Universe is accelerating because time itself is slowing down" [25, 26]. So that according to Senovilla, the speed of time may be related to the "illusions" of dark matter and dark energy estimates. The reason that we have not been able to detect dark matter may just be that it does not exist! String theory as well, may offer an alternative, replacement Proposition to explain the Muon decay time annual decrease. The same concept in string theory (of two independent times and timeframes discussed by Mars, Senovilla and. Vera [25]) has also been suggested in 2014 by Itzhak Bars of the University of Southern California [27]. Unfortunately, the *cause* of the variation of the speed of time becomes an additional quandary.

New mysteries: How does the speed of time vary with time itself and is there a detailed structure to that change? Does the speed of time change depend upon location and "surroundings" in our Universe (e.g., is it unique to the Earth, change with the density of local matter, etc.) and if so what is the relationship? What is the actual theory for the change of the speed of time,

[7] The approximate average speed from the center of the early universe sphere, utilizing Alan Guth's inflationary early Universe theory [24], to the surface is roughly 0.01 meter (one centimeter radius) divided by 10^{-34} seconds = 1032 meters per second. So that in order that information transmission associated with the expanding "material" will not exceed the speed of light of 3 ×108 meters per second, time must be speeded up on average by a factor of about $10^{32} / 3 \times 10^{8} = 3.33 \times 10^{23}$ seconds per second. At that speed up it would take light 10^{-34} seconds × 3.33×10^{23} seconds per second = 3.33×10^{-11} seconds to go from the center of our early Universe to the surface. At the speed of light, 3×10^{8} meters per second, light would have traveled (3.33×10^{-11} seconds) × (3×10^{8} meters per second) = 10^{-2} meters or 1 centimeter as it should. From this large average speed of time it must be reduced (negative) on average by -3.33×10^{23} seconds per second divided by 4.321×10^{17} seconds (seconds since the "big bang") ~ -7.6×10^{5} seconds per second to reach today's time assuming a linear decrease in the speed of time.

that is, what is its cause? Is there a starting point for time? Why is the direction of the time arrow in a single direction? Are there two opposite directions of time flow? Is such a starting point in time an osculation point with other universes? "... apparent, quantum-mechanical 'frenzy' at small scales is nothing more or less than the interface between osculating universes ..." (US Patent 6160336).

WHY SHOULD WE CARE? SPECULATIONS ON THE EFFECT OF THE CHANGE IN THE SPEED OF TIME IN OUR UNIVERSE

Time is ubiquitous among all human endeavors and all scientific enterprise. As a rule of thumb, any process that requires a precision between a microsecond and a quectosecond could be affected by a change in the speed of time. Nano mechanisms in Engineering, quantum mechanics operations in Physics, dark matter in Astronomy, Global Positioning System (GPS) satellite clocks as affected (if the space dimensions of our Universe "scale" change after the big bang does not compensate in location determi-nation) over the years in Space Technology, are examples. Let us start out from the very beginning ... the beginning of our Universe and consider effect of the speed of time then. Let us continue the mile-runner analogy, this time again he runs in the Macrosystem: If the "stopwatches" in our early Universe are running fast, then the apparent time for a mile run lengthened, so that a lower apparent speed for the runner is measured there. However, if there is an apparent shortening of the *standard* mile in the early Universe, as the space dimensions rollout, then the runner traverses an apparently shorter-distance mile. If the two effects are balanced, then one can completely offset the other. More specifically, the smaller apparent measured speed of the runner can be completely offset by the shorter mile and the *intrinsic mile-runner's speed and apparent mile-runner's speeds could be equal!* Such is the analog to the "fast" speed of time together with the "miniature" *standard* meter making the *intrinsic light speed and apparent light speed* equal. Therefore, the contention by Einstein, as to the constancy of the speed of light in all frames of reference, would **not** be violated. In other words, the intrinsic and apparent light-photon speed, or speed of information, could be the same in the early Universe as today.

That is, all physical laws are the same in these space-dimensions and time-dimension changing frames of reference in the early Universe as they rollout and gravity and acceleration remain equivalent. In any event, the early Universe might be speculated to be like a miniaturized *World*, where "... the craftsman moves very fast indeed" from Chapter 8 of [11] (page 85 of the first printing), where activities are just moving more quickly, like an increased frame rate of a movie. Such a miniaturized *World* could initially have a very, very small, perhaps a vanishingly small "standard mile" or standard meter (perhaps to the Planck length) and a very, very fast, perhaps infinitely fast speed of time and a possible "breeding ground" for the *Oh-My-God* particle. Of course, aside from Muon-like "yard sticks" of time, there would be no obvious effects of the speed of time variation measurable in the laboratory if time and space rollout in concert; that is if they rollout such that the increase in space dimensions and slowdown in time preserve the constancy of the speed of light. Since this statement is the crux of the proposed early universe theory let's consider it again, but in more detail. In order to illustrate the situation we now define the mile runner as a "**photon**" and set the runner's speed exactly to a speed limit. Therefore, in accord with proposed theory the length of the "mile-long" track of the race-event must be made equal to the speed limit multiplied by the runner's elapsed macro time required to complete the mile run. But hold on, we are interested in the <u>change</u> of the track length as different trainers having different stopwatches, one slower than the other, make measurements at different times. The <u>slower</u> stopwatch, measuring at a later time, will require making a <u>longer</u> track length than the earlier faster stopwatch mile run. That is a "4-minute mile runner" running at the speed limit as measured at the earlier time, will apparently cover a longer length at the later slow-stopwatch track meet. In fine, the space-dimension <u>itself</u> must change in <u>inverse</u> proportion to the time-dimension's <u>rate</u> of change (speed-of-time change) as time progresses during the lifetime of our Universe. By the way, as a photon the mile-runner's wristwatch has stopped and the runner's speed limit is the speed of light.

Similar to Guth's early-universe inflationary theory, no hard observational evidence currently exists for this conjecture, just an interesting possibility. It is speculated that our Universe gradually slows down (in the time dimension the rate of time slows approaching zero at the end of time) and gradually lengthens (in the space dimensions approaching infinite length at the end of time), both in concert in the seconds and years after the "big bang" or more correctly the ***"BIG ROLLOUT"*** during which ***the speed of light remains constant and all physical laws are preserved at any given time!*** The speculated very early "World" although abiding by all physical laws, would include certain complex electro weak processes (e. g., Muon decay and possibly even electro-weak nuclear reactions of proton-proton chain — affecting stellar luminosity). According to the speculated Proposition such electro-weak complex processes would act according to their own intrinsic clocks and as the rate of macro time of the Universe "approaches" infinity at the beginning of time ("approaches" the start of our Universe, perhaps approaches Planck time; think of a movie running in reverse) their duration would also approach infinity. The mile runner, now again as Muon decay, would hardly move in macro time. The trainer's stopwatch would spin at almost an infinitely high rate, the mile would become "extremely short": e. g., a Planck length distance between the start and finish lines and Planck time interval is analogous to the extremely brief starting pistol's sound time interval — the mile runner is nearly stuck at the start/finish lines at the beginning of time! We must be careful here. The proton-proton chain-reaction process, in a sense like the Cesium-clock process, is speculated **not** to be *complex*, but rather a "simple" energy level change (this time nuclear), and **not** marching to its own intrinsic clock and **not** becoming an incomplete process as the beginning of time is "approached" in the early Universe! This speculation is a Working Hypothesis put forth to stimulate research. Since, according to this speculation, the early Universe may have been in relatively rapid motion as viewed today, relic gravitational waves of high frequency may have been generated. *Thus the detection of high-frequency gravitational waves (*HFGW*s) could reveal the truth, especially as to the speculated initial high speed of time!*

Another interesting feature or possible feature of the speed-of-time variation: it may have several slopes. For example, as we may conclude from the Table and Fig. 3 there may be a variability to the speed of time change (acceleration or deceleration or it may remain constant) i.e., different slopes, during different time periods. In this regard, the speed of time itself as well as the derivatives of the speed of time may be speculated to be increasing to infinity as time "approaches" zero. The analogy is that a movie's frame rate may be increasing without limit: higher and higher and higher... as you "approach" the **beginning** of the movie, that is as you run the film backwards! Therefore, some speculations that speed of time may have a "uniform" or "smooth" variation or *structure,* like a "linear" or "exponential" slow, gradual change, may be incorrect! Figure 3 is a notional graph of what the change of the speed of time might resemble over the years since the big bang or big rollout; that is since time zero or perhaps *Planck time*. According to the speculated speed-of-time variation, the "size" or "value" of the second, minute, hour and year will vary during this progression of our Universe. Note in Fig. 3 the approximate times for the generation of relic HFGWs and relic neutrinos. Later comes the Cosmic Microwave Background (CMB). The actual speed-of-time variation could possibly be estimated by Cepheid-variable or galactic-rotational-rate observations. Further-more, there is no *a priori* reason to suppose that the speed of time may not differ in different parts of our Universe or cannot increase or decrease or it might even *have a detailed structure of discontinuities or abrupt jumps and pauses* not a smooth aesthetically pleasing variation. Because our Universe is not chaotic (as discussed in Chapter 11 of [11]), time cannot reverse or else cause could come after effect! With regard to a detailed structure, it would be quite challenging to measure small changes (*detailed structure*) of the speed of time, but as Morishima [28] mentioned in an article concerning Muon applications: "Muon particles originate from the interactions of cosmic rays with the atoms of the upper atmosphere, and they continuously reach the Earth with ... a flux or shower of around 10,000 Muons per square meter per minute." So that with so much data the possibility of detailed-structure measurement may exist. There may be some measurement device or technique to dif-ferentially measure or find "differences" in a sequence of Muon decay times during such showers, and determine a *detailed structure in the speed of time*!

Galactic rotational rate is involved in dark matter estimates. Think in terms of observing the more rapid rotational of stopwatch's second hand analogy to observing the more rapid rotation of spiral arms of galaxies at higher speeds of time in the past as in Fig. 2**B.** An empirical relationship for estimating galactic rotational rate was formulated by R. Brent Tully and J. Richard Fisher in 1977 on how fast a spiral galaxy "rotated" and its luminosity – roughly speaking the bigger and brighter a galaxy, the faster it "rotated". But a galaxy is not a solid flat disk-like collection of stars that rotate in unison, it is a huge collection of stars each on its own orbit. Therefore, at the galactic edge the rotation is slower, like Pluto's motion about our Sun, and nearer to a central bulge-like galactic sub-halo of stars, it rotates more rapidly, like Mercury's motion about our Sun.

Let's greatly simplify the N-body Lambda cold dark-matter cosmological model for galactic "rotation" by recognizing that the galactic stars, particularly at the outer regions of a galaxy, do not have much gravitational influence on each other and move somewhat like individual spacecraft ("toy" craft) on nearly circular orbits about our Sun. In Astrodynamics or Celestial Mechanics this is called the "two-body" problem or motion and, unlike the motion of three or more bodies (except for special cases), has an exact solution! The central halo mass, m_h , comprises all of the stars, interstellar material and black holes from a star, having mass, m_s, enclosed in the star's orbit. More specifically, it is defined as a halo or "bulge" of stars (interstellar matter and black holes) assumed radially symmetrically distributed according to the Lambda cold dark matter cosmological model. It would be similar to a "toy model" *circular equatorial* satellite orbiting a radially symmetric mass distribu-tion, disc-like Earth. The *Vis-Viva* Energy Integral from Astrodynamics/Celestial Mechanics is given by Eq. (1)—(3) of [29]

$$(ds/dt)^2 = k^2(m_1 + m_2)(2/r - 1/a)$$

where ds/dt — speed of a star or dwarf galaxy = $\omega \times r$, where ω — the angular rate of orbital motion of a star, black hole or dwarf galaxy about the central halo-bulge (radians per second), r is the distance of a star or dwarf galaxy from the center of the galaxy (for example, in meters, astronomical units, light years,

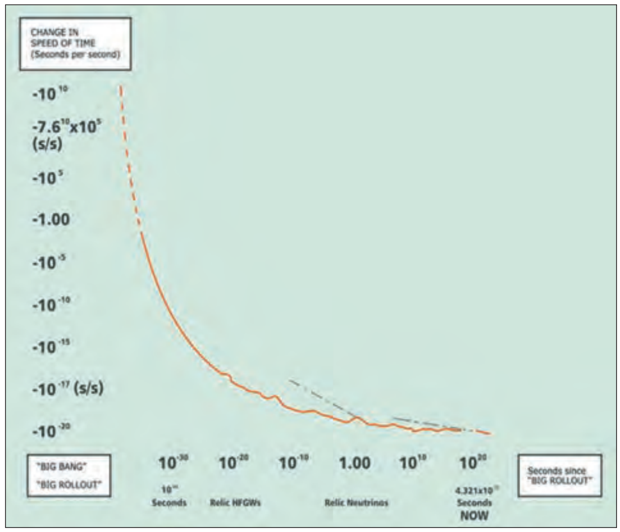


Fig. 3. Notional graph of the change-of-speed-of-time variation with today's time dimension. Notice different slopes (tangents) and irregularities

Note. Such a notional graph of the speed of time versus today's seconds as displayed in Fig. 3, has some philosophical/cosmological consequences. In essence as we view the past through our telescopes (and HFGW detectors), we are not simply viewing 13.8 billion years of "existence" (or even out to the conventional cosmological horizon), but possibly more than 1030 "years" of existence – in fact, an unimaginably, almost infinitely long period of time! The size or value of seconds, minutes, hours, days and years change during this progression of our Universe. Our current Universe may be of a very old age. The phrase "long, long ago and far, far away" of George Lucas' "Star Wars" would take on new meaning. There is much of concern here including the intrinsic "clocks" of some complex processes or sub systems acting on their own "time". Of course, all physical processes as we find them today should remain intact, entropy grows. These processes could essentially continue "forever" that is until the end of time. They will commence at the beginning of time e.g., Planck time, when time "approaches" infinitely fast motion (if viewed from our Century), and will cause the material systems of our Universe (stars, black holes, galaxies, etc.) to evolve, perhaps the ancient "breeding ground" for the Oh-My-God particles. However cradles of intelligent life (possibly advanced by Artificial General Intelligence, Artificial Education (implanted memories) and/or germ-line accelerated evolution and/or combinations thereof) would possibly come and go into "existence" (please see Equation (12-3) of [11] and [18]) over this enormous span of "time"! The hot and dense "soup" of matter in the early universe may or may not have existed. Lots to consider here!

etc.), a is the semi-major axis of the star's orbit, k^2 is a constant, $m_1 = m_h$ the mass of all the stars, interstellar material and black holes within the star's orbit (in solar masses), $m_2 = m_s$ is the mass of the star – but $m_2 << m_h$ so will be neglected, a is the semi-major axis of the star's orbit and, since we assume the star's orbit is *circular*, $a = r$, we have the angular rate of rotation of a star at a distance r from galactic center is proportional to

$$\sqrt{m_h}/r^{3/2}.$$

This relationship is essentially Kepler's Third Law.

The problem is when observations are made it turns out that the value of m_h , as calculated from summing up the masses of all the galaxy's stars, interstellar material and black holes inside a star's orbit, is found to be far too small to account for the rotational rate of all of these galaxy stars! For example, rotational rates do not decrease with distance from the galactic center. Note, however, m_h gets larger at the galaxy's periphery since more stars, interstellar material and black holes are within a star's orbit. If, for example, the galactic distribution of stars and black holes was a homogeneous sphere[8], with an average density in solar masses per cubic light year *independent* of r, then since m_h would be proportional to r^3 and the angular rate ω of stars and black holes in a galaxy would be a constant *independent* of r — this turns out **not** to be the case. In any event, the observed m_h is far, far too small to account for the observed motion of the galactic stars. What to do?

1. Increase the m_h dramatically and the change distribution of the galaxy's mass by assuming there in an almost invisible halo of dark matter in the galaxy or, more exactly, utilize the Lambda cold dark-matter cosmological model.

2. Assume there was a higher speed of time back when the light from the galaxy left to reach our telescopes now and the galaxy's stars appear to have rotated faster (like the hand of the stopwatch in Fig. 2**B**) and the angular rate relationship holds **without need for dark matter**!

3. Or a combination of 1 and 2.

There is also "a cosmological conundrum" [31] in which there are apparently co-rotating satellite systems (e.g., dwarf galaxies) that do not fit the Lambda cold dark-matter cosmological model. If a "toy" model star or dwarf galaxy were on a *polar orbit*, then they might be on a "whirling plane of satellite galaxies" without the Lambda cold dark-matter cosmological model. Perhaps assuming a faster speed of time in the neighborhood of a galaxy might reduce or eliminate the "cosmological conundrum." There is also the Experiment to Detect the Global Epoch of Reionization Signature (EDGES) report detecting the tiny absorption signal of hydrogen clouds that existed between 180 million and 250 million years after the big bang [32]. Certainly the effect of an increase in the speed of time then, compared to the current speed of time at the EDGES microwave detector now, would have a significant role in their experimental analyses. As to Dark Matter in general: "Eighty years after the discovery of Dark Matter, physicists remain *totally stumped* (especially concerning Dark Matter in our Galaxy) about the nature of this non-reflective stuff that, judging by its gravitational effects, pervades the cosmos in far greater abundance than all the matter we can see" [33]. By the way, according to Bertone and Tait [34] there remains "... a sense of crises in the dark-matter particle community" (please see the Appendix).

IS THERE A PERFECT CLOCK OR SOME KIND OF "ABSOLUTE TIME"?

The answer is "no." As Gyorgy Buzsaki and Rodolfo Llinas [35] in their article on "Space and time in the brain" state "... neither clocks nor brains make time per se." One might consider the transient complex process subsystem discussed herein, *itself* as some kind of a clock — e. g., an alarm clock. The problem is you cannot "read" it. If you ask a chef "When will the bread being baked be ready?" She might reply "I don't know exactly." I would ask then "How do you know when it is finished and take it out of the oven?" the chef might reply "I stick a toothpick in it and if some dough no longer sticks to it, then its cooking process is

[8] For example, if ρ is average density of the stars, interstellar material and black holes in a galaxy and totally independent of r, that is not a function of r, then $m_h = \rho\,(4/3)\pi r^3$. In this case the r's cancel and no change in ω for the stars in the galaxy results. The independence of density from r in total is **not realistic**, of course, but this analysis does indicate the importance of the distribution of a galaxy's mass on the variability of ω.

over, but I do not know exactly when that will happen. I cannot read it like a clock you know!" Even if the Proposition proposed herein is false, in the context of the light cones described in Chapter 2 of [11], there is the *impossibility* of distributing "polling-place clocks". which have exactly "polling-place" or absolute time, due to the special and general relativity effects as they are transported to various locations. Even if we attempt to set them by radio signal, since we have imperfect knowledge of the speed of light (and no exact location because of Heisenberg's position uncertainty), it is impossible to accomplish the setting exactly. **Time is really relative!**

A related question is: "what is the definition of the intrinsic, fixed or constant Muon decay time?" or, for that matter the "yard stick" of any *complex*, transient processes or sub system. For the answer let us return to the chef cooking a particular loaf of bread. We ask the chef if there is a particular, specific time that it takes to cook the bread. She may say that there can be, but it depends upon the oven temperature. She may add that when the oven temperature is 300 °F it takes 35 minutes, at 350 °F it takes 30 minutes and at 400 °F it takes 25 minutes. So, again you ask, what is the intrinsic time to bake a loaf of bread? She could say: "The definition of bread cook time depends on the oven temperature, that is, it is 'by definition'. Usually that specific definition is the typical cooking time spelled out in a cookbook for a specific temperature, say 350 °F. So let's use standard-ingredient dough and carefully measure the time from dough placed in oven at 350 °F to clean toothpick extraction and utilize that time as the definition of Standard-bread cook time or yard stick." In our case let us choose the currently most accurate Muon decay time, MuLan [6], of 2,196,980.3 [in 2009.5 picoseconds – remember the size or value of seconds, minutes, hours, days ***and picoseconds change*** during this progression of our Universe] as the "yard stick" or intrinsic, fixed or constant Muon decay time "BY DEFINITION." Actually, similar to Barbour's suggestions [22, 23], we **do not** much care about intrinsic time duration since we are only interested in the approximate occurrence of a chain of events like cooked bread ready to eat and completed Muon decay — it's all relative!

But how do we actually utilize the fixed intrinsic unit of Muon decay time as a "yard stick"? Let us consider a thought experiment: We build a clock whose rate of progression (speed of time or, specifically angular rate of the second hand) is uniform and measure Muon decay time on the date of 2009.5. As was defined this is the "intrinsic unit of Muon decay time" or "yard stick". We now build a clock whose time rate of progression (speed of time) is uniform BUT exactly having a, for example, a 4.2×10^{-19} ps per ps slower rate! Using this slower clock, we again measure Muon decay time on the same date of 2009.5 and jot down the second measured Muon-decay-time value. When in future the measured Muon decay time reaches the second value, we know that the clocks on the Earth at the laboratory site would have a 4.2×10^{-19} ps per ps slower rate — the Muon-decay-time yard stick tells us so! Equivalently one can simply difference each new measurement of Muon decay time from the 2009.5 value and divide by the intervening time interval. The same procedure can be accomplished for other Muon-decay-time dates (since 2009.5 is well in the past) and hence the speed of time will be based upon other newly defined Muon-decay-time yard sticks, hopefully measured to a higher accuracy and precision by advance atomic clocks.

WHAT ARE THE NEXT STEPS?

The next objective should be to determine the variation of the speed of time; to replace the notional Fig. 3 by one constructed from actual speed-of-time data. That objective can be met, at least in part, by the following steps: As previously mentioned, Cepheid variables could assist in the measurement of the speed of time out to about 20 million light years from the Earth. Measuring the rotational rate of galaxies would be a very useful tool *if that rate is attributed to the speed of time not to Dark Matter*. Indications that certain *complex* electro-weak processes, which exhibit longer/shorter durations as the seconds and years of our Universe progress, should be studied. High-frequency gravitational waves (HFGWs), having originated from our early Universe (defined as "relic" gravitational waves) and/or black holes should be analyzed in order to see the effect of a possible high speed of time. Eight different designed or built detectors of HFGWs are discussed in Chapter 10 of [11] and the development of the most sensitive of them, the Li-Baker [36], should be actively pursued. Also as previously mentioned, there should be a measurement device or technique developed to differentially measure or "difference" sequence of Muon decay times in a short time interval, and determine if there exists a detailed structure in the speed of time. Possibly, the Global Positioning System (GPS) satellite clocks would be very slightly affected or **not affected** over the years. Specifically, if the GPS retains **the same** location measurements over the years and there is confirmation of a speed of time change, then it would evidence the continuing rollout of the space dimensions today. Likewise, if the *speed of light* determination **remains constant** as time slows, then there would be additional evidence of the space dimensions continuing rollout today in concert with the speed of time reduction. There also exists "... the unexplained part of the Muon's magnetic moment ..." [37] that might, conceivably, have some bearing on or provide additional data on the variation of the apparent Muon decay time with time if such a variation exists, which I believe it does. The data from the *Gaia* satellite might also shed light on the change in time in our Milky Way Galaxy over more recent times [38], for example, is a variation in rotational rate of orbiting stars, binaries, is in keeping with a time speed change? Finally, but perhaps most importantly, the development of better atomic clocks should be encouraged. Metrologists at the National Institute of Standards and Technology (NIST) found using ytterbium atoms in an optical lattice "... two clocks ticked at the same rate to within 1.4 parts in 10^{18} — just over 100 times better than the top cesium devices" [39]. Approximately, the NIST results translate into an accuracy of up to an attosecond or one millionth of a picosecond! These improvements will become available by "perhaps 2030" [40] and have application to geophysics [41]. If utilized to measure Muon-decay times, then support or falsification of the annual decrease in the length of Muon decay time by means of an appropriate, sophisticated statistical curve-fitting program should quickly ensue. If the Proposition herein speculated is also correct, then a good determination of the speed of time (e.g., Muon decay time) with very accurate clocks over possibly less than a year should provide for an accurate determination of the slowing of the speed of time at least at the laboratory site.

SUMMARY

Here I have speculated based upon review of experimental data from 1946 to 2017 on the duration of Muon decay (please see the Table). A speculations that does not exclude a working hypothesis on the apparent Muon decay time's gradual shortening. I have discussed the Proposition that some complex processes operate on their own clocks different from the clocks associated with our macro Universe. Here I have speculated that the change in the speed of time in our Universe is directly related to the presence or absence of dark matter and dark energy and the Hubble parameter. Completely independent of the correctness of the Proposition, I have proposed an early universe theory of the big rollout of spacetime, from vanishingly small space dimensions, e. g., Planck length, to today's dimensions, and time slowing from approaching infinitely fast speed (nearer to time "zero" or Planck time) to today's speed, to be tested by the detection of high-frequency relic gravitational waves.

APPENDIX

Sunday, February 18th, 2018 Professor Chris Tully of Princeton University, Dr. Aron Chou Sr. of the Fermi National Laboratory and Dr. Kathryn Zurek of the Laurence Berkeley National Laboratory presented papers on the detection of Dark Matter at the Annual Meeting of the American Association for the Advancement of Science (AAAS) held in Austin, Texas. On that same day I was invited to give a "Poster Presentation" also concerning Dark Matter (https://aaas.confex.com/aaas/2018/meetingapp.cgi/Paper/22030). In lectures in 1990—1992, as part of West Coast University's Engineering Master's Degree curriculum, I discussed the rollout of our Universe in both time and space. The first published account of this speculation, at least as to the high speed of time in the early Universe, was on page 85, Chapter 8 of the first printing of reference [11] published on July 16, 2016. Other presentations concerning my discovery or speculation as to the speed of time variation can also be found in footnote 5, page 54 of [18]: http://spacescitechjournal.org.au/en/archive/2017/3/05 and Appendix B of [13] a draft of which was emailed to me by Andrew Beckwith in September, 2017.

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РОБОЧА ГІПОТЕЗА ПРО СКОРОЧЕННЯ ПЕРІОДУ МЮОННОГО РОЗПАДУ І ЧАС

Земна атмосфера пронизується космічними променями, що виходять із міжзоряного простору. Коли космічні промені стикаються з атмосферою Землі, вони розпадаються на мюони. Ці мюони також розпадаються з декількома різними режимами розпаду протягом точно виміряного часу (від шести до восьми значущих цифр). Мюони можуть бути представлені як годинник, який може працювати швидко або повільно.

У статті аналізується робоча гіпотеза про те, що тривалість розпаду мюона, отримана в експериментах у 1946—2017 роках, яка повинна бути постійною, може поступово скорочуватися, можливо нерегулярно (включаючи паузи), приблизно з 2.330 мкс (1946 г.) до 2.202 мкс (1962—1963 рр.). Виникають питання щодо точності найостанніших проведених вимірювань; потрібно також провести точніші експерименти, щоб підтвердити або відкинути тенденцію поступового скорочення часу розпаду мюона. Зокрема, у період з 2007.0 по 2009.5 роки більш точні вимірювання часу розпаду мюона показують зменшення видимого часу розпаду мюона приблизно на 13 пс в рік. Виявлено, що чисельний тренд не є статистично значущим. Проте явне зменшення часу розпаду мюона не може бути абсолютно виключене відповідно до огляду представлених даних.

Припущення про причини можливого скорочення часу розпаду мюона пов'язане з можливою зміною ходу годинника (швидкий або повільний годинник) у Всесвіті. Робоча гіпотеза полягає в тому, що власний час розпаду мюона не зменшується незначно порівняно з його власним годинником, але його явний час розпаду трохи зменшується у порівнянні з ходом годинників, пов'язаних з нашою Землею і / або нашого Всесвіту. У статті аналізуються декілька опублікованих досліджень про нерівномірність часу в нашому Всесвіті. Пропонується, що деякі складні процеси або підсистеми, такі як розпад мюона, «рухаються» до свого власного, фіксованого «часу» або часового інтервалу, який не залежить від потоку «часу» в нашому Всесвіті. На підтримку цього припущення цитуються декілька опублікованих досліджень. Обговорюються приклади застосування гіпотези можливої зміни швидкості часу в різних наукових задачах.

Ключові слова: мюон, тривалість мюонного розпаду, швидкість часу, високочастотні гравітаційні хвилі, реліктові гравітаційні хвилі, темна матерія, темна енергія, ранній Всесвіт, великий вибух, велике розгортання.

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РАБОЧАЯ ГИПОТЕЗА О СОКРАЩЕНИИ ПЕРИОДА МЮОННОГО РАСПАДА И ВРЕМЯ

Земная атмосфера пронизывается космическими лучами, исходящими из межзвездного пространства. Когда космические лучи сталкиваются с атмосферой Земли, они распадаются на мюоны. Эти мюоны также распадаются с несколькими различными режимами распада в течение точно измеренного времени (от шести до восьми значимых цифр). Мюоны могут быть представлены как часы, которые могут работать быстро или медленно. В статье анализируется рабочая гипотеза о том, что длительность распада мюона, полученная в экспериментах в 1946—2017 годах, которая должна быть постоянной, может постепенно сокращаться, возможно, нерегулярно (включая паузы), приблизительно от 2.330 мкс (1946 г.) до 2.202 мкс (1962—1963 гг.). Возникают вопросы, касающиеся точности самых последних проведенных измерений. Требуются также более точные экспериментальные данные, чтобы подтвердить или отвергнуть тенденцию постепенного сокращения времени распада мюона. Так, в период с 2007.0 по 2009.5 годы более точные измерения времени распада мюона показывают уменьшение видимого времени распада мюона примерно на 13 пс в год. Обнаружено, что численный тренд не является статистически значимым. Тем не менее, явное уменьшение времени распада мюона не может быть абсолютно исключено в соответствии с представленными данными измерений. Предположение о причине возможного сокращения времени распада мюона подразумевает, что оно связано с возможным изменением хода часов (быстрые или медленные часы) во Вселенной. Рабочая гипотеза состоит в том, что собственное время распада мюона не уменьшается незначительно по сравнению с его собственными часами, но его кажущееся время распада немного уменьшается по сравнению с ходом часов, связанными с нашей Землей и/или нашей Вселенной. В статье анализируются несколько опубликованных исследований на тему неравномерности времени в нашей Вселенной. Предлагается, что некоторые сложные процессы или подсистемы, такие как распад мюона, «движутся» к своему собственному, фиксированному «времени» или временному интервалу, который не зависит от потока «времени» в нашей Вселенной. В поддержку этого предположения цитируются несколько опубликованных исследовательских работ.

Ключевые слова: мюон, длительность мюонного распада, скорость времени, высокочастотные гравитационные волны, реликтовые гравитационные волны, темная материя, темная энергия, ранняя Вселенная, большой взрыв, большое развертывание.