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MUON-DECAY TIME SHORTENING AND ITS POSSIBLE CAUSE: THE SPEED OF 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 show that the duration of Muon decay, which should be a constant, definitely ***appears*** *to shorten gradually from 1946 to 2017 from very roughly 2.330 microseconds (1946) to very roughly 2.202 microseconds (1963) to very roughly 2.078 microseconds in 2017. From 2007.0 to 2009.5 the more precise Muon decay time measurements produce a decrease in* ***apparent*** *Muon decay time of very approximately* 6×10^{-4} % per year. Although found not to be a statistically significant *well-defined* numerical trend, *certainly the* ***apparent*** *decrease in Muon decay time actually exists and cannot be ruled out. 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) on 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. 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 that is independent of the flow of "time" in our Universe is proposed and several published research papers cited to support it. 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 Universe, dark matter and dark energy as well as theories about the beginning of our Universe (big bang). For example, a big rollout of spacetime from vanishingly small space dimensions and infinitely fast speed of time to today's values; testable by detection of relic high-frequency gravitational waves.*

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

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 show that the duration of Muon decay, which should be a constant, definitely **appears** to shorten gradually from 1946 to 2017 from very roughly 2.330 microseconds (1946) to very roughly 2.202 microseconds (1963) to very roughly 2.078 microseconds in 2017. From 2007.0 to 2009.5 the more precise Muon decay time measurements produce a decrease in **apparent** Muon decay time of very approximately 6×10^{-4} % per year. Although found not to be a statistically significant well-defined numerical trend, certainly the **apparent** decrease in Muon decay time actually exists and cannot be ruled out. 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) on 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. 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 that is independent of the flow of "time" in our Universe is proposed and several published research papers cited to support it. 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 Universe, dark matter and dark energy as well as theories about the beginning of our Universe. For example, a rollout of spacetime from vanishingly small space dimensions and infinitely fast speed of time to today's values.

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Table 1.	**Trend of**	**Length of**	**Muon Decay Time**	**Versus Time**
Date of Measure ment	Muon Decay Time (Picoseconds)	Estimated Error (Picoseconds)	Muons at Rest or in high-speed Cosmic-ray generated Motion?	Reference
1963.0	2,202,000	±3,000	At Rest	Eckhause, et al.[2]
1973.0	2,197,300	±300	At Rest	Duclos/ Chin. Phys.[1]
1974.0	2,197,110	±80	At Rest	Balandin/ Chin. Phys.[1]
1984.0	2,196,950	±60	At Rest	Giovanetti/Chin. Phys.[1]
1984.0	2,197,078	±73	At Rest	Bardin/Chin. Phys.[1]
2007.0	2,197,013	±21	At Rest	Chitwood/Chin. Phys.[1]
2008.0	2,197,083	±32	At Rest	Barczyk/Chin. Phys.[1]
2008.5	2,197,030	± 40	At Rest	Coan & Ye [3]
2009.5	2,196,980.3	±2.2	At Rest	Webber/MuLan [4]
2013.0	2,196,980.3	±2	At Rest, probably copy of 2009.5 measurement	Tischchenko/ChinPhy[1].
2015.0	2.110	±70,000	Fast, Cosmic Ray[1]	Barazandeh [5]
2015.0	2.1650	±403,000	Fast, Cosmic Ray[1]	Barazandeh [5]
2016.0	2,078,000	±11,000	At Rest	Physics OpenLab [6]
2017.0	2,080,000	± 11,000	At Rest	Adams[7]

[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 measurement due to time dilation and tend to validate these two recent measurements. Moving clocks run slow due to time dilation; so Muon decay time observed in an At Rest, ground frame of reference is longer as the 2016 and 2017 show. A picosecond is a trillionth of a second, or 0.000,000,000,001 seconds.

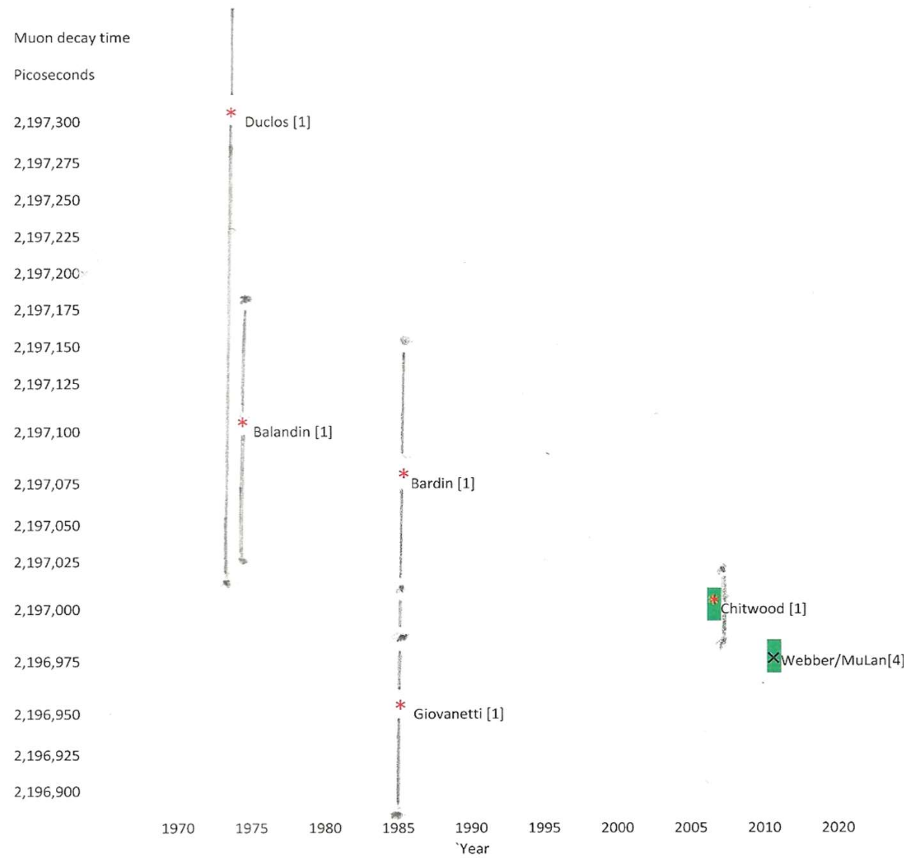

Fig. 1a Muon decay time measurements and error from 1973 to 2009 from Table 1

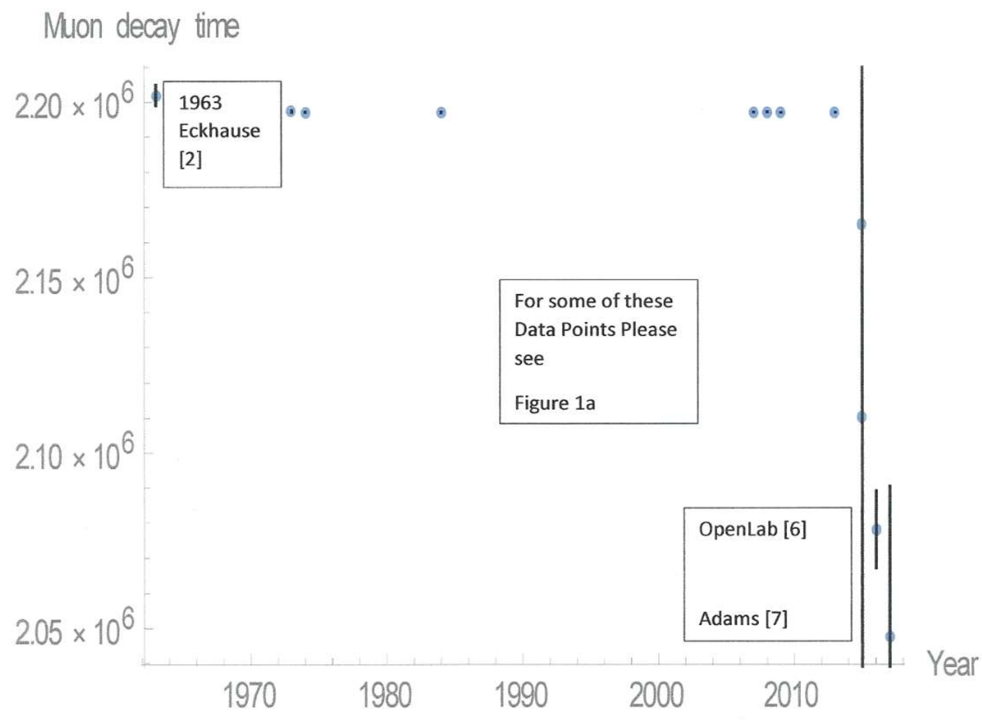

Fig. 1b Muon decay time, picoseconds, from 1960 to 2017, except for Text Boxes, from a reviewer. The earliest Muon decay time that the author could find was measured in 1946 and was **(2.33± 0.15) ×10^6 ps**, but too approximate for detailed analysis: http://www0.mi.infn.it/~neri/HomePage/Teaching_files/Esperimento_CPP.pdf

In Fig. 1a the measurements (*) appear clearly to exhibit a **trend** to longer decay time as the years go by. Figure 1b shows experiment data collection from 1963 to 2017 and suggests a much shorter Muon decay time in 2016 and 2017. On the other hand, as remarked by a reviewer: the data from [6], 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 [6] claim: "The value that is obtained is probably slightly underestimated since the frame window taken into examination had up to 7 μsec. This value is, however, in agreement with the result that you should get which stays between the theoretical value of **2,2 μsec for positive muons** which is equal to the value measured in empty space and the value of **2,04 μsec for negative muons** which are affected by the interactions with the nuclei of the scintillator material" (emphasis by the authors of [6]). For this reason data from [6] will be excluded from further detailed analysis. It is emphasized again that only a data **trend** that has been observed, but it certainly **does not rule out** a decrease in Muon decay time over the years. From the more comprehensive Table 1, which includes estimated errors, it definitely appears that there is a significant decrease in very approximate Muon decay time from 1963 (2,202,000 ±3,000 ps) to 2017 [7] (2,080,000 ±11,000 ps) or -122,000 ps. The *errors are quite large* so that over the 2017 – 1963 = 54 years the Muon decay time change, if but one extreme error outlier (a standard deviation) to the other would be (2,202,000 – 3,000 = 2,199,000) – (2,080,000 +11,000 = 2,091,000) = -108,000 ps difference. If 3 standard deviations (99.7% probability), then (2,202,000 - 3×3,000 = 2,193,000) – (2,080,000 + 3×11,000 = 2,113,000) = -80,000 ps or, over the 54 years, or about -1,500 ps per year. This value is still very approximate, especially considering the equipment errors such as found in the data presented in [6]. For this reason, let us consider in detailed numerical calculation **only** the more accurate MuLan collaboration values from Table 1. The combined results (circa 2009-2010 or 2009.5) due to MuLan give Muon decay lifetime = 2,196,980.3 (±2.2) ps, which is more than a dozen times as precise as previous experimental measurements [4]. The previous 2007 determination given in Olive/Chin. Phys. [1] by Chitwood (2007) of 2,197,013 (± 21) ps and depicted in in Fig. 2 of [4], 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** picoseconds, which is a *more precise* calculation. (The variation in decay time is quite small as a percentage: (33ps/2,197,000 ps) × (100%/2.5 yrs.) = 6 × 10^{-4} % per year.) 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) it "…is less than 2sigma (95% probability)…", and therefore this numerical estimate is not statistically significant. There is no justification, however, to accomplish a more rigorous statistical analysis until more precise data are obtained. On the other hand, these arithmetic examples and examination of the Muon decay lifetimes in Table 1and Fig. 1a definitely provide observational evidence that there **is a *trend*** *of shorter 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 definitely indicate and 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**. Therefore it is also fair to speculate on what the consequences or *application* of such a trend would be.

Speculation on the possible reduction in 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 search was to find very precise data, to six to eight significant figures, taken over many decades. Muon decay was one of those transient processes or quantum mechanical subsystems, 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 analyses. As footnoted in Table 1, 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 [2] is **not** that the intrinsic Muon decay time (or any other electro-weak decay time) is decreasing with time; specifically, not the 6×10^{-4} % per year, which amounts to 100%/6×10^{-4} % = 170,000 years to **vanish** – a mere instant of time astrophysically speaking and not observed! **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.) × 1.37×10^{10} yrs. = **0.18 seconds**! Of course it is suggested that this speed change is just the tail of a **series of significant time-speed changes** over the billions of years since the "big bang." 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 such a 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 "yardstick" 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 four-minute talk and single Poster were presented on this discovery and its applications at the Annual Meeting of the *American Association for the Advancement of Science* in Austin, Texas on February 18, 2018.

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[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. It is essentially an encouragement for further research and analyses.

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, Chemistry, Engineering and Astronomy. Poincaré 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. As will be discussed, Muon decay time may be a measurement means to the determine speed of time (clocks running fast or slow) in our Universe. 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" [9]. Furthermore, according to Andrew W. Beckwith [10]: "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 [10], italics and bold type added for emphasis in these quotes.) As suggested in an email by Giorgio Fontana: "Muon decay time can be considered to be an **absolute time ruler** and separate from the timeframe as measured in our Universe" [11]. 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***" [12] - 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 multiple-step 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. [13]

The truth of the Proposition, as symbolized in Fig. 2, depends upon the measured disparity (e.g., Table 1) 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**, for example by cesium atomic clocks and pendulums (stopwatch shown in **B)**. **It is speculated therefore, that the slowdown of time in our Universe, local to the Earth, can be**

measured by Muon-decay time acting as an "absolute time ruler." The Proposition should manifest itself in all the weak processes including radioactive decay and stability of atomic nuclei. Other than Muon decay, other such evidence should be sought. Atomic clocks may be able to 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 and possibly add data in support of the **Proposition** ***or falsify it*****!**

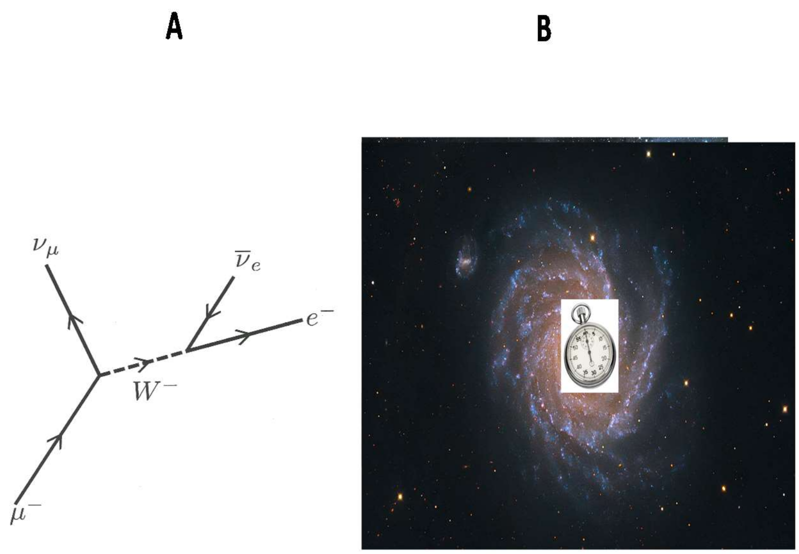

Fig. 2. Subsystem A of Muon decay and Macrosystem B for example a galaxy and its rotational rate (like the rotation of the hands on a clock as viewed at a several billion year earlier time, would be rotating faster if time is moving faster at these past times)

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 with the years or, for that matter, other similar independent transient, complex subsystems that do not show an annual decrease. That is, the **Muon decay time change would be ruled out**. 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 and Gloria Garcia Cuadrado, (also contained in [14]) who report: "… the existence of two times as part of general relativity: time t and proper time tau …" and suggests "…that a space-time is associated to a solution of a primordial gravitational wave equation and indeed the speed of time slows down and Muon decay time shortens…I suggest that this is the motivation for the slowdown of time: a cosmological gravitational wave."

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 does 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) over the years, perhaps decelerating from a very high speed in the early universe, as discussed in Appendix B of [10] and Chapter 8 of [8], 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 [9], [16], [17] and, especially, in Carlo Rovelli's Book [18].

According to Julian Barbour [19, 20]: "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 15], 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 stop watches were moving 5 minutes/4 minutes = -1.25 minutes/minute or, equivalently, second per second times faster 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 [3]. 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.

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[3]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 8 and Appendix B of 10]. Alan Guth at Cornell proposed the theory that our Universe was "inflating" and that in a remarkably short time of 10^{-34} seconds the Universe became the size of a marble [21]. Working the arithmetic[4] 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. That is, all physical laws are contended to be the same in these frames of reference moving at a given velocity.   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 could not be over the "speed limit" of information.

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[4] The approximate average speed from the center of the early universe sphere, utilizing Alan Guth's inflationary early Universe theory [21], to the surface is roughly 0.01 meter (one centimeter radius) divided by 10^{-34} seconds = 10^{32} meters per second. So that in order that information transmission associated with the expanding "material" will not exceed the speed of light of 3×10^{8} 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.

It may be that the speed of time is slowing from that speculated early very high rate. 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, José 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" [22, 23]. 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 [22]) has also been suggested in 2014 by Itzhak Bars of the University of Southern California [24]. 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 depending upon location and "surroundings" in our Universe and if so what is the relationship? What is the actual theory for the change of the speed of time, that is, what is its cause?

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 an attosecond 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 determination) 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: 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 frames of reference moving at a given velocity in the early Universe 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 [8], 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 and a very, very fast, perhaps infinitely fast speed of time and then gradually slows down (in the time dimension) and lengthens (in the space dimensions) in the years after the "big bang" or "big rollout." Since 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 (**HFGWs**) could reveal the truth!*

Another interesting feature or possible feature of the speed of time: it may have several slopes. For example, as we may conclude from Table 1 and Fig. 3 there may be a variability to the speed of time change (acceleration or deceleration) i.e., different slopes, during different time periods. 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 time might resemble over the years since the big bang or big rollout. Note 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. Furthermore, there is no *a priori* reason to suppose that the speed of time cannot increase or decrease or it might even *have a detailed structure of discontinuities or abrupt jumps* not a smooth aesthetically pleasing variation. Because our Universe is not chaotic (as discussed in Chapter 11 of [8]), 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 [25] 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 differentially measure or find “differences,” in a sequence of Muon decay times during such showers, and determine a *detailed structure in the speed of time*!

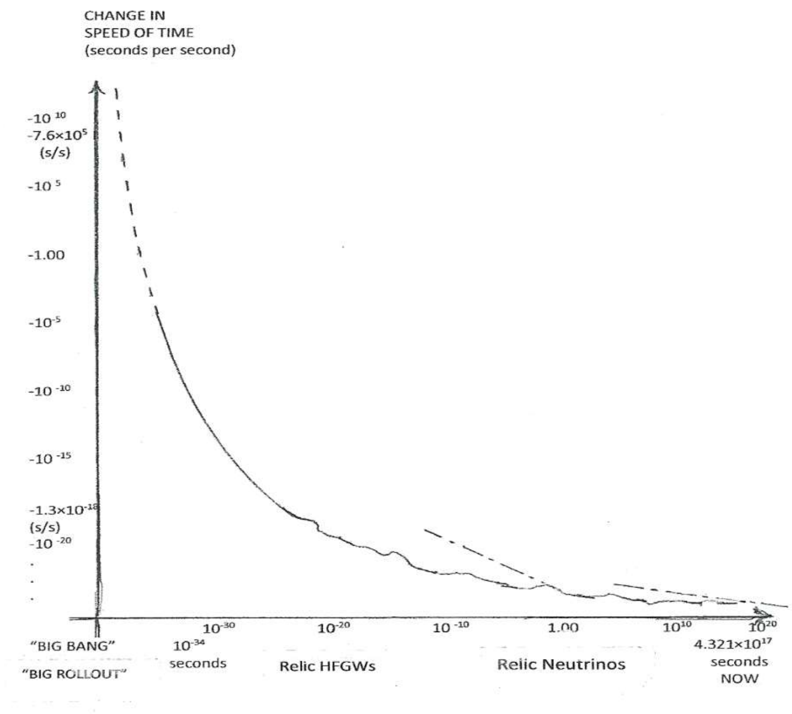

Fig. 3. Notional graph of the change of speed of time variation with time. Notice different slopes (tangents)

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 (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 distribution, disc-like Earth. The *Vis-Viva* Energy Integral from Astrodynamics/Celestial Mechanics is given by Eq. (1-3) of [26]

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

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, 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 $m_2 \ll m_h$ 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[5], 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. What to do? 1. Increase the m_h to more than 4×10^{12} to 12×10^{12} solar masses 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 (Fig. 2 **B**) and the angular rate relationship holds without need for dark matter! 3. Or a combination of 1 and 2. The third alternative may be best to explain galaxies found lacking in dark matter [27].

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[5] 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.

There is also “a cosmological conundrum” [28] 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 [29]. 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.” [30].

Is there a perfect clock or some kind of “absolute time”? The answer is “**no**.” As Gyorgy Buzsaki and Rodolfo Llinas [31] 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 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 [8], 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!**

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 useful tool if that rate is attributed to the speed of time not to dark matter. High-frequency gravitational waves (HFGWs), having originated from our early Universe (defined as "relic" gravitational waves), should be analyzed in order to see the effect of a possible high speed of time. Eight detectors of HFGWs are discussed in Chapter 10 of [8] and the development of the most sensitive of them, the Li-Baker [32], 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 reduction, then it would evidence the continuing rollout of the space dimension today. Likewise, if the speed of light determination

remains constant as time slows, then there would be additional evidence of the space dimension continuing rollout today in concert with the speed of time reduction. There also exists "… the unexplained part of the Muon's magnetic moment …" [33] that might, conceivably, have some bearing on the variation of the apparent Muon decay time with time. The data from the *Gaia* satellite might also shed light on the change in time in our Milky Way Galaxy over more recent times [34], for example, a variation in rotational rate of orbiting stars 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" [35]. Approximately, the NIST results translate into an accuracy of an attosecond or one millionth of a picosecond! If utilized to measure Muon-decay times, then support or falsification of the annual decrease in the length of Muon decay time should ensue. If the Proposition herein speculated is also correct, then a good determination of the speed of time over possibly less than a year ***should provide for an accurate determination of the slowing of the speed of time at the laboratory site!***

Summary:

Here I have shown based upon experimental evidence that the duration of Muon decay, which should be a constant, definitely appears to shorten gradually from 1946 to 2017. Here I have proposed that the Muon decay time gradual shortening is due to the reduction in the speed of time. Here I have speculated that the change in the speed of time is directly related to the presence or absence of dark matter and dark energy, the Hubble parameter and an early universe theory of the big rollout of spacetime, from vanishingly small space dimensions to today's dimensions, and time slowing from an infinitely fast speed to today's speed.

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ANALYSES OF SPEED OF TIME BASED ON MUON LIFETIME-DECAY AS A TRANSIENT TIME

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Introduction

General Description of the problem:

This presentation is based upon an observation (*Discovery*) by the author that the duration of Muon decay, which should be a constant, appeared to shorten from 1963 to 2017 as the years passed by. The motivation for the observation was the author's earlier conjecture that the speed of time might have been very fast in the early Universe, due to the limit on the velocity of information, and that its speed may still be slowing down from that high speed. Prior research on the speed of time had been published by Jose Senovilla, Marc Mars and Raul Vera who in 2008 speculated on time slowing related to the expansion of our Universe.

Goals of the study: Since the dawn of civilization on Earth, "time" has been an essential concern of humanity in general and Physical Science in particular. Poincaré 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. But what if our clocks have been and still are slowing since they may have been moving very fast at the beginning of our Universe? That question is the subject of this presentation.

Description of methods: Unlike the *intrinsic* 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 such *intrinsic* process time of a sub system is unlike the period of a pendulum, which depends on its length and the strength of gravity. Such cesium-atom level changes and pendulum swings are the "stopwatches" of our Universe and can be utilized to measure the apparent duration of Muon decay and determine the "speed of time" (*Application*). **The Proposition here is that some processes or sub systems are "marching" to their own intrinsic "time" or timeframe that is independent of the flow of "time" in our Universe.** Andrew Walcott Beckwith, Report for the *27th Solvay Conference in Physics* , October 2017 Section XVII stated: "… the issue Dr. Baker has raised is suggestive and should be thoroughly analyzed. The author 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 Schrodinger who postulated that quantum *sub* systems, of a macrosystem definitely exhibit quantum mechanical time dependent behavior. Equation (31) is not quantum mechanical, but it is a sub system, and so the same rule by Schrodinger, as to sub systems *exhibiting definite time dependence*, may be applicable here, i.e., **think in terms of time variance**. "

Results & Discussion

The truth of the Proposition depends upon the measured disparity between sub system processes, which should always have the same duration in their time frame, for example Muon decay, and the duration as measured in our Universe's time frame, for example, by cesium atomic clocks. Such measurements could support **or falsify** the Proposition.

Of course, there may well have been overlooked systematic errors, which somehow could have been related to the particular "age" or sophistication of the measurement devices utilized or different decay modes. Such systematic errors might reduce the Muon decay time measurements with time even though there was no real change in Muon decay time. On the other hand, such systematic errors, which have been utilized in the provisionally selected slowdown value, would have needed to have been comprehensive of **all** of the five or six experimental devices, which led to the data utilized, and overlooked by **all** of the Muon experimenters from 1963 to 2017 and is unlikely.

RESULTS:

*Over the period 2007 to 2009, the Muon lifetime change and time slowdown in our Universe near Earth has a provisional value of approximately **-41 (± 22) ps per year** (ps $=10^{-12}$ s, a picosecond).

*If linear, then over 13.7 billion years (1.37×10^{10} years) since the "Big Bang", clock speed would be reduced by about 0.568 seconds (small changes in the ephemerides of the planets, moons or spacecraft and galaxies appear to rotate a bit faster).

*It is speculated, however, that the speed of time decrease since the early universe could possibly be exponential starting out very fast; with time and other dimensions just "unroll out," and then gradually slowing down in the years after the Big Bang, therefore possibly affecting galaxy rotation (**dark matter** indicator), expansion of our Universe, etc.

* If linear, then the *clock of time would run down* in 3.154×10^7 s/yr/4.1×10^{-11} s $= 7.4 \times 10^{17}$ s and divided by 3.154×10^7 s/yr or 2.4×10^{10} years or 2.4 trillion years for our Universe ("**End of Time**"). But again, the speed of time is speculated to be slowly decreasing (its actual variation possibly estimated by Cepheid-variable or galactic rotation observations) so it might just approach zero as a limit.

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