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

Robert M L Baker, Jr.[1] www.drrobertbaker.com

[1] Transportation Sciences Corporation, Palm Desert, CA 92260, USA

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. The author conjectured previously that time moved very fast in our early Universe and that it might still be slowing down from that maximum speed. The author also speculated that the variations in the speed of expansion and/or the rotational rate of galaxies may result in whole or in part on the speed of time. The research presented herein involves a determination of the long-term rate of change of time based upon Muon lifetime decay as an intrinsic transient time of a very accurately measured process or sub system having its own time frame that co-exists with our Universe's time. This paper is based upon an observation or discovery by the author that the duration of Muon decay, which should be a constant, appeared to shorten as the years passed by. A search for the explanation of that effect led the author to frame a Proposition in which the Muon decay time is a fixed time frame coexisting with and separate from the time as measured in our Universe. The speed of time is the rate of progression of time along the dimension of time in our Universes spacetime continuum. It is concluded that the slowdown of time local to the Earth, over the period 2007 to 2009 is approximately - 42 (±22) picoseconds per year. The Conjecture is that the speed of time might change over the years, as expressed by an apparent shortening of Muon decay time, decelerating from a very high speed in the early universe and that we are now measuring the "tail" of that change.

This paper is based upon an observation or *Discovery* by the author that the duration of Muon decay, which should be a constant, appeared to shorten as the years passed by. A search for the explanation of that effect led the author to frame a Proposition in which the Muon decay time is a fixed time frame coexisting with and separate from the time as measured in our Universe. The 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. This conjecture was to explain the ability of "material" or perhaps "information" in the possible inflation of the early universe to reach the size of, say, a one-centimeter radius sphere in about the estimated 10^{-34} seconds without exceeding the speed of light (*1*, *2*). Of course, nothing prevents the universe itself from expanding faster than light. For example, a lighthouse beacon projected image can at a great distance "move" in excess of light speed. But, assuming the "material" of an early universe contains information even expanding like the dots on a bellowing balloon cannot "take" or "move" information to another "dot" position faster than light speed. The author also 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. Unfortunately, the *cause* of the variation of the speed of time becomes an additional quandary. Perhaps the answer lies in the unification of general relativity and quantum mechanics or is it "a riddle, wrapped in a mystery, inside an enigma …" **TIME** may be the ***key!***

As was mentioned in (*3*), according to Julian Barbour (*4*): "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 you are a trainer of a 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 (quite a bit smaller than the 3.33×10^{23} second per second average estimated (*2*) for the early universe) times faster than today's stopwatches. (His runner's wristwatch and heart beat were relatively slower than the other trainer's stopwatches would have shown the previous year.)

Is there a way to establish that clocks (stopwatches) were moving with higher "speed" in the past? Essentially, a new experiment may **not** be required. If there is a process having transient time that has been measured accurately by atomic clocks, then one should examine records and determine if a statistically significant reduction of the transient time, for example, Muon decay time over several years has occurred (*5*). If so, then the atomic clock "stop watches" must have been all running fast in the past and the speed of time was different and these clocks are still very slightly slowing down now after the Big Bang. Unlike the *intrinsic* process of Muon decay, one second is defined as the time that elapses during 9,192,631,770 cycles of the radiation produced by the change between two energy levels of the cesium 133 atom. Also such *intrinsic* process time (e.g., Muon decay) 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); so it also is not a *transient* process time or a "sub system." Such cesium-atom 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 can be utilized or *applied* to measure the *apparent* time intervals (process *transient* time) of sub systems like Muon decay. **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.** The truth of the Proposition depends upon the measured disparity between 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.

A Muon is an elementary particle similar to the electron, with a negative electric charge, a spin of ½, but with a much greater mass than an electron. Muons decay, with several different decay modes, over a well measured *intrinsic* process time (e.g., measured by cesium atomic clocks) and almost always produce at least three particles, which include an electron and two neutrinos. Because their *intrinsic* lifetime or *constant* decay time has been very accurately measured over many years, they represent a possible means, as a transient time, to establish the

speed of time. Of course time, like 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 spacetime continuum of our Universe. We propose that the speed of time in our Universe might change over the years, decelerating from a very high speed in the early universe, as discussed in (*1*) and Chapter 8 of (*6*), especially Exercise 8.2.There is ongoing debate over the meaning of time and the constancy of the speed of light and other astrodynamic constants and the foregoing analyses and notions are open to considerable debate as in references (*7*), (*8*) and (*9*). As part of that debate, the utilization of the Muon decay time as a transient for independently establishing the change in the speed of time in our Universe is discussed herein.

As Beckwith states *(10)* "… 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 (51) 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**. " Please see Section XVII of (*10*).Thus we think in terms of the ***co-existence*** *of different time frames*: that of a Muon *sub system* (transient process time) and that of our Universe, a macrosystem – essentially Beckwith restates the aforementioned **Proposition.** In addition, Professor Giorgio Fontana (was Head of the Electronics Laboratory of the Department of Physics of the *University of Trento* and also a contributor in the field of quantum randomness) states "Therefore average Muon decay time is an *absolute time ruler*." (*11*)

Analyses of Muon Decay Time

The following analysis are based upon the MuLan Collaboration. Specifically, Fig. 2 of Webber, et al. (*12*) is a Muon-Lifetime measurement summary. The MuLan R06 and R07 results are included in Fig. 1. Even more recent studies by Olive, et al. (*13*) are also considered.

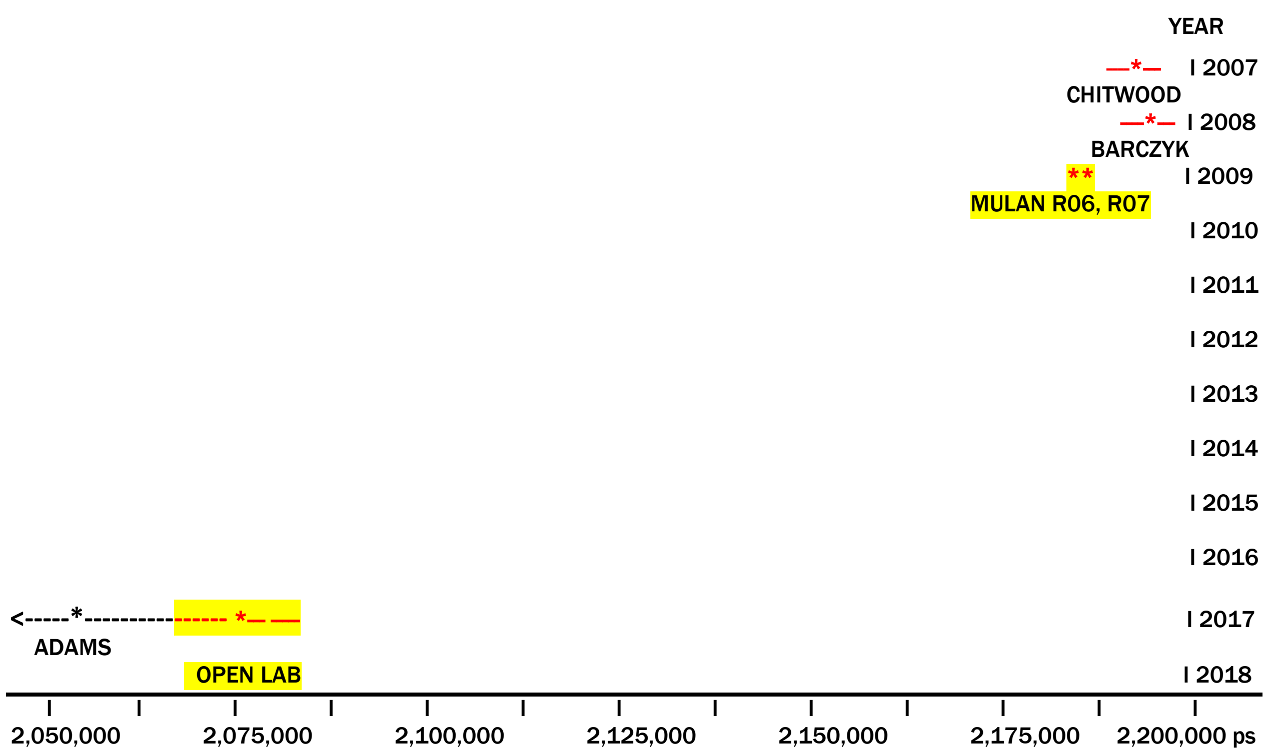

Fig. 1. Muon Delay Time versus Year inspired by Fig. 2 from D. M. Webber, et al., the MuLan Collaboration (*12*).

The combined results (circa 2009-2010 or 2009.5) due to MuLan give Muon decay lifetime = 2,196,980.3 (±2.2) ps, a dozen times as precise as any previous experiment. On the other hand, the two previous determinations given in Olive, et al. (*13*) by Chitwood (2007) of 2,197,013 (± 11) ps and Barczyk (2008) of 2,197,083(± 15) ps and depicted in in Fig. 2 of (*12*) and in Fig. 1, show a decay time shortening, with respect to the MuLan value, of -34.7 picoseconds and – 104.7

picoseconds for Chitwood (2007) and Barczyk (2008), respectively. The slowdown for Chitwood over 2009.5 – 2007 = 2.5 years is -13.9 picoseconds per year and for Barczyk over 2009.5-2008 = 1.5 years is – 69.8 picoseconds per year. The reports by Balandin (1974), Glovanetti (1984) and Bardin (1984) given, for example, in (*14*) and/or (*15*) were either too inaccurate or too old and unreliable or both to include. There is an important point to be made: the random error determination for Balandin (1974), Glovanetti (1984) and Bardin (1984) is not provided in detail in the references examined by the author, whereas the MuLan Collaboration provides detailed random error analyses for Chitwood (2007), Barczyk (2008), MuLan R06 and R07. Therefore, the Balandin (1974), Glovanetti (1984) and Bardin (1984) measurements simply indicate that between 1974 and 1984 the Muon decay time was "on the order of " 2,190,500 ps.

The accuracies of measurements are shown in Fig. 1 by red lines between outliers centered on the measurement. We will essentially pivot about the MuLan value (*12*) so that the slope S1 to the one outlier end of the Chitwood measurement is

S1 = 2,196,980 – [(2,197,013 – 11) = 2,197,002] = - 22 ps / 2.5 years = - 9 ps per year. (1)

The slope S2 to the other outlier end of the Chitwood measurement is

S2 = 2,196,980 – [(2,197,013 + 11) = 2,197,024] = -44 ps / 2.5 = - 18 ps per year. (2)

The slope S3 to one outlier end of the Barczyk measurement is

S3 = 2,196,980 – [(2,197,083 -15) = 2,197,068] = -88 ps/ 1.5 = -59 ps per year. (3)

The slope S4 to other outlier end of the Barczyk measurement is

S4 = 9,196,980 – [(2,197,083 + 15) = 2,197,098] = -118 / 1.5 = -78 ps per year. (4)

The arithmetic average is: (-9 - 18 - 59 -78)/4= -41 ps per year. For the error we take the rms average of the outlier-slope differences √ $[(18 - 8)^2 + (78 - 59)^2]$ = 22 ps per year. Consideration of Fig. 2 of (*12*) incorporated in Fig. 1 and the forgoing arithmetic, supports the view that, over the period 2007 to 2009, the Muon lifetime change is approximately **-41 (± 22) ps per year** (ps $=10^{-12}$ s, a picosecond).

If linear in their prediction of the speed of time, 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 (almost astrodynamically imperceptible). It appears more likely; however, that the speed of time decrease since the early universe would probably be exponential starting out very fast, time and other dimensions just "unroll out," and then gradually slowing down in the years after the Big Bang. We might, therefore, now be measuring the tail of the speed of time slow down. Perhaps, Cepheid-variable star frequency would provide a possible determination of the overall speed of time variation. In the other time direction, since there are 3.154×10^7 seconds in a year, the *clock of time would run down* in $3.154 \times 10^7/4.1 \times 10^{-13} = 7.4 \times 10^{19}$ s/3.154×10^7 or 2.4×10^{12} or 2.4 trillion years for our Universe ("End of Time"). But again, the speed of time is probably an exponential so it would just approach zero as a limit.

Recent Measurement of Muon Decay Time and Conclusions

Recent, 2017, data are provided in, for example, (*15* - *16*) and exhibited in Fig. 1, found the Muon decay time as: 2,047,270 (± 43,021) ps. (*15*). Even more recently, as discussed in (*16*) and depicted in Fig. 1, the Muon decay time was found to be: 2,078,000 (± 11,000) ps at about 2017.5. (Exact date of measurements is uncertain as is the determination of random error; please see (*14*) for details.) A weighted average of these two measurements could be taken to be representative of the estimated decay time for 2017. However, since it is the larger decay time (to be on the conservative side), has the lowest error and is probably the most recent, we will choose the *Physics OpenLab* (*16*) result as the estimated decay time for 2017. Let us connect both outlier ends of the MuLan (*12*) and the *OpenLab* (16) measurements together and averaging the slopes of these lines. We find:

Slope 1 = [(2,078,000 -11,000) – (2,196,980 +2.2)] = -129,982.2/ (2017-2009.5) = -17,331 ps/year (5)

Slope 2 = [(2,078,000 +11,000) – [(2,196,980 -2.2)] = -107,977.8/(2017-2009.5) = -14,397 ps/year. (6)

Thus, the rate of slowdown is about (slope 1+ slope 2)/2 = -15,864 ps per year.

By the way, one of the earliest measurements was in 1963 [*17*] and was 2,202,000 ± 3,000 ps. It was one of the largest measurements of negative-Muon lifetimes in light Isotopes, reported. The overall slowdown over 54 years from 1963 to 2017 would be

Slope 3 = [(2,078,000 -11,000) – (2,202,000 + 3,000)] = 2,067,000 -2,205,000 =

- 138,000 ps /(2017-1963) = -2,556 ps per year (7)

Slope 4 = [(2,078,000 +11,000) – (2,202,000 – 3,000)] = 2,089,000 -2,199,000 =

- 110,000 ps/ (2017-1963) = -2,037 ps per year. (8)

Thus, the rate of slowdown is about (slope 1+ slope 2)/2 = -2,296 ps per year.

Although these are very large slowdowns, the associated large errors suggests they are seriously inaccurate and will be neglected, but serve to validate that a slowdown in the speed of time exists. Furthermore, such large slowdowns would, probably have been detected in the change in the ephemerides of orbiting planets, moons and spacecraft. The situation is similar to the Balandin (1974), Glovanetti (1984) and Bardin (1984) measurements with questionable random error, in that these recent measurements simply suggest that “around 2017” the Muon decay time was “on the order of “ 2,060,000 ps. Comparing this transient time with the 1974 – 1984 value “on the order of” 2,190,500 ps, about 43 years earlier, yields a slowdown of about -3,000 ps per year, but its error of at least ± 11,000 ps renders this value as also unacceptable. Please see Table 1.

Therefore, because it has relatively far less documented random error associated with it, we will provisionally select the former, approximate **-41 (±22) ps per year**, slowdown estimate from the far more accurate 2007 – 2009 subset of measurements. In any event, the trend, as apparently confirmed by the two 2017 measurements and the old 1963 measurement, is for the Muon (decay) lifetimes to decrease with time and the speed of time to slow after the Big Bang. Atomic clocks may be able to measure different transient processes (sub systems), both on Earth and in space, that can improve this estimate of the reduction of the speed of time and possibly add data in support of the **Proposition** ***or falsify it*****!**

Table 1. Larger, Very Approximate Speeds of Time Computed between Two Measurement Pairs and their Possible Effect.

Larger, Very Approximate Speeds of Time Computed between the Following Two Measurement Pairs	Almost Immeasurable Possible Effects
• ***MULAN*** **Muon (*12*) decay lifetime = 2,196,980.3 (±2.2) ps, 2009.5, *Physics OpenLab* (*16*) lifetime = 2,078,000 (± 11,000) ps, 2017.5** **-15,864 ps per year** • **Eckhause et al. (*17*) lifetime = 2,202,000 ± 3,000 ps, 1963 *Physics OpenLab* (*16*) lifetime = 2,078,000 (± 11,000) ps, 2017.5** • **-2,296 ps per year**	• **Ephemerides of planets, moons and spacecraft** • **Rotational rate of Galaxies (involved in Dark Matter estimates)** • **Hubble parameter (roughly related to the acceleration of our Universe)**

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 four 2007 – 2009 data points that determined the provisionally selected value, would have needed to have been comprehensive of all of the five or six experimental devices and decay modes that led to the data points of Fig.1, and overlooked by all of the Muon experimenters from 1963 to 2017 and is unlikely. There are other decay time measurements in this time range, but tend to be either of significantly larger random error or difficult to time tag as to measurement date.

Postscript

Other accurately measured quantities over the years could also be considered such as the speed of light, somewhat like the speed of a mile runner. In the case of light speed however, there would be an interesting relationship to the "constancy" of the speed of light during a possible inflation of the early Universe. Either clocks there might need to be very "fast" in order for the "material" of the early, possibly rapidly inflating Universe, not to exceed the speed of light and/or the speed of light there might be considerably faster (continuing the *runner* analogy "older shorter length mile, *apparently* faster four-minute-mile *runners* during the early universe versus newer longer mile, apparently slower four-minute-mile *runners*" in modern times where runner's *"speed"* [like the **constant** speed of light] remains unchanged, but the mile has lengthened). In this case, the **apparent** speed of light may be subject to a measurable decrease as time progresses after the Big Bang. That change as well as the constancy of other astrodynamic constants (Baker, et al. (*18*) and (*19*)) are subjects for continuing debate and future study. But hold on! If in the mile-runner analogy the "stopwatches" in the early Universe are running fast and the apparent time for the mile run lengthened, then the shortening of the *standard* mile in the early Universe may be completely off-set by the speed of time increase and the apparent speed of the runner can be completely or partially offset and the intrinsic and apparent speeds could possibly be equal! Therefore, the intrinsic and apparent light-photon speeds could be the same in the early Universe as today and *there would be no change in the speed of light!* In any event, the early Universe might be like a miniaturized *World*, Fig. 2, where "… the craftsman moves very fast indeed" from Chapter 8 of (*6*). The miniaturized *World* could have very small "standard mile" or standard meter (itself defined by the speed of light in a vacuum) and very fast time. The speed of time decrease since the early universe would probably be exponential, starting out with very fast time and very small other dimensions, which just "unroll out," and then gradually slowing down and lengthening in the years after the Big Bang.

Such comments may seem simplistic, but paraphrasing Einstein "It should be possible to explain cosmology to a barmaid." Since the early Universe may have been in relatively rapid motion, gravitational waves of high frequency may have been generated. Thus the detection of high-frequency gravitational waves could reveal the truth.

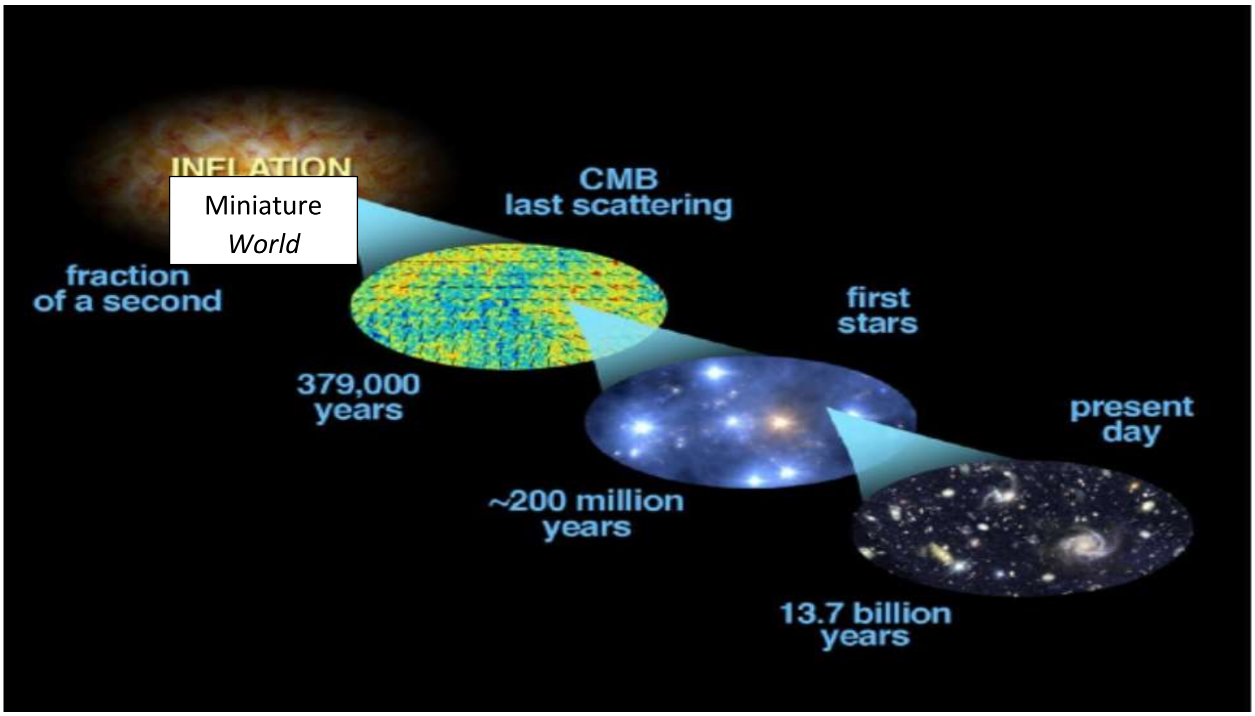

Fig.2. Development of our Universe (adapted from PowerPoint Presentation of Fangyu Li, in 2016 with Permission).

Is there a perfect clock or some kind of "absolute time"? The answer is "no." As Gyorgy Buzsaki and Rodolfo Llinas (*20*) in their article on "Space and time in the brain," state "… neither clocks nor brains make time per se." One might consider the transient process, sub system itself as some kind of a clock – e.g., an alarm clock. The problem is you cannot "read" it. My wife, Bonnie, is a great cook. One morning I asked her "When will the bread being baked be ready?" Bonnie replied "I don't know exactly." I replied, then how do you know when it is finished and take it out of the oven?" "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 (*6*), there is the *impossibility* of distributing "polling-place clocks," which have exactly "polling-place" or absolute time, due to special and general relativity effect 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!**

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