Does the Cosmos have two times? Multi-time and cosmic acceleration

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We put forward a multi-time theory, in frame of which the cosmic acceleration is a natural phenomenon without cosmological constant or anything like that. The main point of this theory is that each of the gravity interaction and electromagnetic interaction has its own time, respectively. Also we give a concrete model of this theory which can exactly simulate ΛCDM. Further we discuss the possible observations which may improve this theory in the future.

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Time is one of the most ordinary and profound concept, for the public and for scientists. From the ancient times, numerous philosophers, humanists and poets offered creative ideas about time one after another. However, the following point is persisted in the modern science: A quantity which can not be measured quantitatively is not qualified as the object of science. According to this rule, “space”, as an object of science, founds on the rigid body. We can imagine a world of mollusca. Creatures living in such a world can never quantitatively measure a distance, as shown in Fig 1. In fact, it is not necessary for them to develop the notions such as metric, or metric space, though they can develop topology.

Similarly, the scientific concept of time founds on periodic motion. Time, in everyday life, may just denote event sequence, or psychological time, such as one car goes after another. When we see the cars go one after another, the ink disperses in water, or the galaxies are recessing, we know that time is flowing. If we just stop on “event sequence”, we can never quantitatively measure an interval of time (Maybe we can develop a subject like time topology). We have to refer to a motion with repetition property. Fortunately, the Nature presents a type of motion which can help us to quantitatively measure the interval of time: It is periodic motion. To measure the size of a space, we need to put a ruler (rigid body) between two extremes one time after another to fill the space, with an accuracy to the length of the ruler itself. To measure an interval of time, we need to observe how many cycles undergone in such an interval, with an accuracy to the period of the cycle itself. Hence, the periodic motion is necessary to quantitatively measure an interval of time.

In the case of space measurement, we can freely shift the same ruler back and forth, which ensures that the space

FIG. 1: The concept of space roots in the existence of rigid bodies. In a world of mollusca, how can they get the concept of distance?

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interval is gauged by the ruler into segments with the same length. However, the case of measurement of time is very different because the crucial property of time: Irreversibility, which makes that the idea of equal of two periods one after the other is not as clear as the first sight. We can measure an interval of time by a periodic motion. But we can not verify that the period of this cycle equals the last one. Philosophers and mathematicians noticed this point many years ago. Locke was aware of that “no two parts of duration can be certainly known to be equal.” [1] Leibniz wrote: “our measure of time would be more accurate if we could keep one day past to compare with days to come, as we keep the measures of space.” (translated by the author) [2]. Poincare also mentioned this point [3]. He said, “...2. There is no absolute time. When we say that two periods are equal, the statement has no meaning, and can only acquire a meaning by a convention. 3. Not only have we no direct intuition of the equality of two periods, but we have not even direct intuition of the simultaneity of two events occurring in two different places...” The Poincare’s point 2 is essentially the same as of Locke and Leibnitz’s. Both of them stress that it is impossible to compare the successive time segments. We know that the Poincare’s point 3 triggered special relativity. On the contrary, the point 2 never get enough concerns. This problem highlights the irreversibility of time. For the case of space, we can take the same ruler to measure the length of the different segments of a line by shifting the ruler freely, back and forth. But a time interval passed, and passed for ever. No clock can confirm that the last second is equal to this second. We say they are equal is only, in fact, a convention, or a stipulation.

If we can not know whether the two successive time segments are equal indeed, or it is just an improper question, a concession is to find a natural convention for this equality. An isolated periodic system without dissipation (There is no energy transfer between macroscopical motion and microscopic motion.) seems a natural candidate, that is, we stipulate that the time passed in every period is equal if the system of periodic motion is in isolated state without dissipation. We call a system satisfying these conditions a perfect system to measure time (PSMT). Approximately, the earth-sun system, earth-moon system, a mechanic clock with spring, are approximately PSMT, and have been used to measure time for many years. Sure, any realistic system is not rigorously isolated and has more or less dissipation. But this does not prevent us from acquiring the concept of quantitative time, as we obtain the concept of metric space without perfect rigid body.

If we have a PSMT, an immediately subsequent question whether all PSMTs be synchronised. To answer this question we need to study the mechanism of the PSMTs. There are several different types of periodic motions which are commanded by different interactions. In spite of developments in unite theory in physics, the 4 (or 3) interactions we know today are inherently different all the same, especially the gravity is remarkably different from other three gauge interactions. In as much the interactions are intrinsically different we have no transcendental reason to assure PSMTs controlled by different interactions can be synchronised for ever, which means the time velocities may different in systems controlled by different interactions.

In a periodic system controlled by one interaction, we have a natural convention, that is, time flows equably in a PSMT. But, how about the conventions of the systems controlled by different interactions? If we apply our natural conventions to two different system, one is controlled by gravity and the other is controlled by electromagnetic interaction, we are not sure whether the two conventions are identified. This idea seems delicate so here we explain it explicitly by an example. We have two systems : the earth-sun system and a simplest light clock. The light clock is composed by two parallel mirrors, A and B, whose reflectivity is 100% and a photon travels back and forth between the two mirrors, as shown in fig 2. The light ray is vertical to the mirrors. The time that this photon starts from mirror A to mirror B and then returns back to A we call a “tick”. We arrange the two mirrors in appropriate distance to ensure the light clock passes 10^{10} ticks when the earth rotates a circle around the sun. But in the interval that the earth rotating the sun next circle the light clock passes 10^{10} + 1 ticks. We suppose both of the two systems are at perfect isolated states. So under this condition we have to accept that the notion of time derived from periodic system of gravity is inherently different from notion of time derived from periodic system of electromagnetism, because we have no transcendental reason to infer that the convention in the first system is superior than that of the second or vice versa. We have to admit that there are two inherently different times.

Though philosophers and mathematicians such as Locke, Leibniz and Poincare have sensed the problem of equability of successive time segments, we are indifferent to the time conventions of different systems in concision sciences up to now. We don’t know how to set up a concrete scientific theory to describe it because of the deficiency of experimental data. The recent cosmological observation, which implies the universe expands more and more faster, offers an operative effect to test whether the conventions in different PSMTs are the same or not. First we display a toy model to show how the multi-time theory works in cosmology. In this toy model our main goal is to show why a decelerating universe in gravity time can be treated as an accelerating universe in electromagnetic time. In a spatially flat FRW universe filled with dust, the scale factor is

\[ a(u) = (u/u_0)^{2/3}, \]

where \( a \) is scale factor, which is shared by electromagnetic time and gravity time, \( u \) is gravity time, \( u_0 \) is the gravity
age of the universe and the scale factor has been scaled to 1 at the present epoch. Clearly, in the view of gravity
time $u$, the universe decelerates all the time. If the gravity time $u$ is a linear function of the electromagnetic time $t$,
we can always rescale $u$ to make $u$ identify with $t$. It is only a trivial case in which the universe decelerates in view
of electromagnetic time all the same. Giving a most simple nonlinear relation of gravity time $u$ and electromagnetic
time $t$ as follows,

$$u = t^2,$$

we obtain deceleration parameter according to electromagnetic time $t$,

$$\frac{1}{a} \frac{d^2a}{dt^2} = \frac{4}{9} t^{-2}.$$  \hfill (3)

From (3), the universe becomes accelerating in view of electromagnetic time in this naive toy model 2, which may
be helpful to explain the marvelous acceleration of our universe [4].

Note that all our clocks are electromagnetic systems or other gauge interaction systems. A mechanical clock with
pendulum may be treated as a periodic gravity system. In fact, the pendulum swings for a long time mainly because
of the unwinding of mainspring, not the gravity. So it must also be taken for electromagnetic system. In a word,
“time” we used in all the measurements and observations by a modern clock is electromagnetic time (we assume other
gauge interactions share the same time with electromagnetic interaction). If we are aware of gravity has an inherent
different time concept, the accelerating universe is easily understood.

Now we turn to a more realistic multi-time model to simulate $\Lambda$CDM. The spatially flat $\Lambda$CDM model becomes the
new standard model of cosmology since it well fits the present observation data, especially the luminous distance data
of type Ia supernovae. However, the amplitude of the cosmological constant $\Lambda$ greatly deviates from its theoretical
predication, approaching the order of $10^{122}$. This deviation is accredited as the most serious deviation between theory
and observation in the history of science. Such a severe problem indicates that cosmological constant may be only an
illusion.

We have several strong evidences that dark matter exists in our universe, whose partition is much larger than that
of ordinary matter (baryon matter). The standard cold dark matter model (SCDM) supposes that our universe is
spatially flat and filled with dust. All the expansion data can be explained in such a dust universe with a specific
relation of gravity time and electromagnetic time. Especially, all the expansion facts which can be described by
$\Lambda$CDM exactly re-present in SCDM with the following relations,

$$\ddot{u} = \frac{1}{r} \sinh r\dot{t}.$$  \hfill (4)
Here $\dot{r} = \Omega^{1/2}_A(\Omega_{mt}\Omega_{mu})^{-1/2}$, $\dot{u} = u\sqrt{\Omega_{mu}}$, $\dot{t} = t\sqrt{\Omega_{mt}}$.

It is better to make some explanations of the above equations and symbols. First of all, we have two scenarios of the universe. The traditional scenario (TS) is that all the laws of nature share the same time, in which $\Lambda$CDM’s prediction is well consistent with observations. Multi-time scenario (MTS) is that gravity and electromagnetic fields cherish their own times, respectively. $\Omega_{mu}$ and $\Omega_A$ are the present partitions of dust and cosmological constant in TS, respectively. $\Omega_{mt}$ and $\Omega_K$ are the present partitions of dust and curvature in MTS, respectively. $\ell$ and $u$ are the scaled electromagnetic time and gravity time in MTS, $\ell = H_{0t}t$, $u = H_{0u}u$. The electromagnetic time $t$ in MTS is identical to the universal time in TS. Hence we use the same mark $t$ to denote both the electromagnetic time in MTS and the universal time in TS. $H_{0t}$, $H_{0u}$ are the present Hubble constants defined by electromagnetic time and gravity time, respectively. 

In cosmology, the scale factor is a freely adjusted quantity up to a constant factor. Here we just set that the gravity time and electromagnetic time share the same scale factor, ie, $a_u = a_t = a$.

From (1), one sees that $\dot{u}$ is identical to $\dot{t}$ in the very early universe while $\dot{u} \sim e^\ell$ in the late time universe. This is to say that gravity time flows at the same rate (up to a constant factor) as electromagnetic time in the early universe but flows much faster than electromagnetic time in the late time universe. So in late time universe, when a supernova recesses a distance the gravity time it experienced is more longer than the electromagnetic time it experienced, which yields the fact that the supernova looks much swifter in view of electromagnetic time. This is the essence of the present apparent acceleration in MTS.

Now we would like to concern more technic details for our real universe. More precisely, some evidences imply that the dark matter together with the luminous matter still cannot flat the universe. So in MTS there will be no enough matter to flat the universe, whose spatial sector becomes hyperbolic (KCDM). In this case, all the expansion facts which can be described by $\Lambda$CDM also exactly represent in a hyperbolic universe with the following relations,

$$\ell = \frac{2}{3\sqrt{\Omega_K}} \ln \left[ \sqrt{1 + r^2 \left( \frac{\cosh(\sqrt{\Omega_K} \phi) - 1}{2} \right)^3} + r \left( \frac{\cosh(\sqrt{\Omega_K} \phi) - 1}{2} \right)^{3/2} \right],$$

(5)

$$\ddot{u} = \frac{\Omega_{mu}}{2\Omega_K} \left[ \frac{1}{\sqrt{\Omega_K}} \sinh(\sqrt{\Omega_K} \phi) - \phi \right],$$

(6)

$$r = \frac{\Omega_A \Omega_{mu}^3}{\Omega_{mt} \Omega_K^3}.$$  

(7)

Here $\Omega_K$ is the present partition of curvature in MTS. $\ell$ and $u$ are the scaled electromagnetic time and gravity time, which are implicitly related by a medium parameter $\phi$ in (3) and (4).

As we have mentioned, all of our tools to measure time in scientific experiments (observations) is electromagnetic time. We have no idea to measure the gravity time in cosmology directly up to now, which yields a great difficulty to distinguish MTS from TS by expansion facts. If we cannot tell a prediction which is different in MTS and TS, the theory of gravity time in MTS is only a superfluous try. Fortunately, we find that MTS really tells some interesting predictions on the velocity of gravity (wave) and equivalence principle.

The gravity (wave) propagates at a different velocity measured by electromagnetic time from that of light in MTS, if we suppose that the gravity (wave) propagates exactly at the light velocity measured by gravity time. First we point a gauge freedom of $u$. For a constant $b$, if we set $u \rightarrow bu$ and replace $H_{0u}$ by $b^{-1}H_{0u}$, nothing changes in the above discussions. Thus, without losing any universality, we set $H_{0u} = H_{0t}$, that is, the gravity time and electromagnetic time share the same present Hubble parameter. In a small space interval $ds$, the gravity (wave) velocity in gravity time $V_g$ relative to what in electromagnetic time $V_e$ reads,

$$V_g = \frac{V_g}{V_e} = \frac{ds/du}{ds/d\ell} = \frac{d\ell}{d\dot{u}},$$

(8)

where we have used $H_{0u} = H_{0t}$. In the case of perfect simulation of $\Lambda$CDM by KCDM in frame of MTS, we obtain

$$V_g = \left( \frac{\Omega_{mu}a^{-3} + \Omega_Ka^{-2}}{\Omega_{mt}a^{-3} + \Omega_A} \right)^{1/2}.$$  

(9)

So measured by electromagnetic time, the gravity (wave) velocity is a variable in the history of the universe. Clearly, $V_g$ goes to $(\Omega_{mu}/\Omega_{mt})^{1/2}$ in the very early universe while it becomes zero in the far future. Fig 1 illuminates the evolution of $V_g$ in the history of the universe.
Therefore, a certain prediction of MTS is that the gravity velocity in the history of the universe is variable. Some evidences imply that the present velocity of gravity is approximately equal to the velocity of light \( \frac{c}{v} \). However, its uncertainty is still too big to constrain \( \Omega_{\mu} \) and \( \Omega_{nt} \). The gravity imprints its track of propagation in the early universe. Also the structure formation process will be different if gravity and light travel at different velocities. We expect that we can find some clues of the velocity of gravity in the history of the universe in cosmic microwave background and the large scale structure.

At last, we say some words on the framework of the theory. First, we have two time coordinates in MTS in an FRW universe. A natural proposition is that the gravity time together with the three space coordinates obeys the general covariance principle if we want to inherit as much achievements of general relativity as possible. The electromagnetic time is a parameter which does not directly construct the 4-geometry of the space-time. In a chart other than FRW, the relation between the gravity time and electromagnetic time will formally holds, that is, it is still \( (4) \) or \( (5) \) and \( (6) \). Under this assumption, electromagnetic time is a gravity-induced quantity. Second, we assume that the electromagnetic time and gravity time are identified up to a constant factor in a stationary time (with a time-like Killing vector). So we can still enjoy the splendid successes of special relativity and general relativity in the Solar system.

Now we conclude this letter. We analyzed in detail that the different interactions share the same time concept is not an axiomatic conclusion. We put forward that the present cosmic acceleration is natural if gravity and electromagnetic fields do not share a unique time (MTS), without introducing any additional exotic matters or any additional structures of the 4-spacetime. Furthermore, we present a certain testable predication of MTS, that is, the velocity of gravity is a variable in the history of the universe. Our future works include: To verify MTS or defy it by observation, to explore it by fundamental theory, i.e., to present a fundamental demonstration of the relation of electromagnetic time and gravity time, not only put it phenomenologically etc.

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