Could time be logarithmic?

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This talk and accompanying paper can be downloaded from www.turbulence-online.com. Comments welcomed.

The origin of this talk – driving late at night listening to public radio.

- This talk really began almost exactly one year ago as my wife and I were driving to Boston, the evening before the APS/DFD meeting.
- There was a Canadian program, *'As It Happens'*, on the Boston NPR station discussing dark energy and dark matter. Several eminent scientists were being interviewed.
- Somehow in our midst 90% of the mass (or 'dark matter') is very much present but invisible, and seemingly completely undetectable.
- And it affects pretty much nothing (except astronomical events that happened long ago).
- The same was true for 'dark energy' as well: Somehow this mysterious source was making the universe expand against gravity.

The origin of this talk – driving late at night listening to public radio.

- As I listened I made a comment to my wife: "I have seen many bad measurements in my life, including some of my own. But I have never found 90% of anything really missing. It was always the equations I was that were wrong!"
- And I made a prediction that this would be the case for dark matter and dark energy.
- But what could be missing? At the core of the observations was a large difference between the mass inferred from luminosity of galaxies and comparison with our Sun, and that inferred from rotation – effectively what was just Newton's Law.
- And I had a pretty sleepless night trying to imagine how that could be and what could be missing. How could something as simple as Newton's Law be wrong? How could 'mass' be missing?

Pubs can be important for more than just fluids.

- The next day I met Marcus Hultmark and Clay Byers (both from Princeton) for lunch at a pub across the street from the meeting venue.
- We were discussing what eventually evolved into our soon to be published paper in the Lumley edition Phys Fluids.
- One of our key points of was that time evolves logarithmically in decaying turbulence. The flow does not expand, but all of the length scales increase with time linearly.
- In the middle of a Ruben, it struck me like a flash of lightning that perhaps the universe evolves the same way – as a similarity solution to Einstein's field equations – a solution in which the scales grow but the universe does not.
- That may still indeed be true. But this talk is about another hypothesis: **That time itself may be logarithmic.**

What is absolute time? Or LOGARITHMIC TIME?

- Let's DEFINE **absolute time**, say t, to be the time measured in linear increments since the beginning of time – the Big Bang if you will.
- Note that a Big Bang does not imply the universe must be expanding. It could have been a BIG BANG in an infinite universe. But this really doesn't matter to us. We just pick an arbitrary place whence begins our current epoch.
- And we DEFINE **logarithmic time**, say τ as the log of absolute time normalized by some arbitrary time scale. I.e.

$$\tau = \ln(t/t_o) \tag{1}$$

where t_o is the arbitrary time scale.

Why logarithmic time? Why not some other function?

- Mechanics is all about time differences. Any new hypothesis must be consistent with our old ideas. I.e., the old ideas have to have been 'almost right', and the differences undetectable for the past 500 years.
- Logarithmic time satisfies this, since if the difference in two times is δt, then the difference in logarithmic time is:

$$\delta\tau = \ln(t + \delta t)/t_o - \ln(t/to) \quad (2)$$

$$= \frac{\delta t}{t} + \left[\frac{\delta t}{t}\right]^2 + \cdots \quad (3)$$

- But t until now is about 13.8 billion years — 13.8×10^9!!!!
- And we have been doing mechanics for only about 500 years. So to see the leading error term could at most be 3.6×10^{-8}, even if we had started with Galileo! Time would have seemed linear!

Is there really no way to tell the difference?

- Probably not! Logarithmic time differences are indistinguishable from linear time – at least in time on earth.
- Even the absolute time starting with Galileo is pretty much indistinguishable from the present absolute time, since they differ by an unmeasureable amount.
- And any constant multiplied by absolute time will also appear constant.
- ONLY BY LOOKING FAR BACK IN TIME – TOWARD THE BEGINNING OF TIME – MIGHT WE SEE DIFFERENCES.
- And see clues that our equations might be wrong!

Logaritmic time derivatives are different.

- If time were really evolving logarithmically, than the time derivatives in our natural laws would have to be expressed as **logarithmic derivatives**; i.e.,

$$\frac{d}{d\tau} = \frac{d}{d \ln t/t_o} = t\frac{d}{dt}. \tag{4}$$

- Thus all our previous derivatives would have to be multiplied by asolute time, t.
- But we would not have been aware of this, since t has varied so little over our human existence, much less our experiments.

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Logarithmic velocity and accelerations

- For a non-expanding spatial coordinate system, the logarithmic velocity would be given by:

$$\vec{V} = \frac{d\vec{x}}{d\tau} = t\frac{d\vec{x}}{dt} = t\ \vec{v} \quad (5)$$

where $\vec{v}$ is the linear time velocity.

- And the logarithmic acceleration, $\vec{A}$, by:

$$\begin{aligned} \vec{A} &= \frac{d\vec{V}}{d\tau} = \frac{d^2x}{d\tau^2} && (6) \\ &= t^2\frac{d\vec{x}}{dt} + t\ \vec{v} && (7) \\ &= t^2\left\{\vec{a} + \frac{\vec{v}}{t}\right\} && (8) \end{aligned}$$

where $\vec{a}$ is the linear time acceleration. $|\vec{a}|/t << 10^{-9}m/s^2$.

- So the conclusion is if time were indeed logarithmic, then our replacement for Newton's Law probably should be:

$$\begin{aligned} \vec{f} &= m^* \frac{dV_p}{d\tau} && (9) \\ &= m^* t^2 \left\{ \frac{d^2 \vec{x}_p}{dt^2} + \frac{1}{t} \frac{dx_p}{dt} \right\} && (10) \\ &\approx [m^* t^2] \, \vec{a}_p && (11) \end{aligned}$$

- Thus for all times not close to the very beginning of time, what we thought was the mass, m, is approximately the true *cosmic mass*, m^*, times the age of the universe squared; i.e.,

$$m \approx m^* t^2 \qquad (12)$$

- Clearly the farther back we travel in time for our observations, the more important the departures from the classical Newton's law become.

Implications for Newton]s Law of Gravity

- Newton's gravitational law is commonly written as:

$$F = G\frac{m_1 m_2}{r^2} \tag{13}$$

  where $G = 6.67408 \times 10^{-11}\ m^3/kg\ s$ to one part in 4.7×10^{-5}.
- There is nothing fundamental about gravity which changes if we change our equations to reflect a dependence on logarithmic time.
- We would need, however, to change the definition of mass and the gravitational constant to reflect the differences.
- I.e, if time were logarithmic, then $m = m^* t^2$. And we would rewrite the gravitational law as:

$$F = G^*\frac{m_1^* m_2^*}{r^2} \tag{14}$$

  where $G^* = G\ t_p^4$ and where t_p is the absolute time we made the measurement of G.

A simplistic explanation of why astronomers think there is 'Dark Matter'

- First, they estimate the mass, m, in a galaxy (or pair of them) by measuring their luminosity and comparing it to our sun.
- And they have estimated the mass of the sun by applying Newton's gravitational law and Newton's law for a rotating system (all in $t \approx t_p$ of course).
- Then they measure the rotation rate of a pair of galaxies (all when $t << t_p$ since it took billions of light years to travel here), and apply the same gravitational law to it to determine the mass.
- And the two estimates don't agree. And they differ by a lot –70 to 80%!
- So they infer that there must be a mysterious '*Dark Matter*' to make the equations balance.
- A simpler explanation might be that time is logarithmic – as suggested earlier.

A possible explanation for 'dark matter'

- Suppose this really is the right gravitational law:

$$F = G^* \frac{m_1^* m_2^*}{r^2} \tag{15}$$

where G^* is the real gravitational constant
- The relation of G^* to what we previously thought was the gravitational constant, G is $G^* = G\ t_p^4$ where t_p is the absolute time we made our measurements of G (i.e., now!).
- It would seem there is no problem applying the old law, since the t_p^4 in G^* cancels the two t^2's in $m = m^* t^2$.
- And that is true **but only at the present time**! I.e. as long as $t = t_p$.
- When we try to apply the old law far back in time (like to rotating galaxies), $t << t_p$. So we overestimate gravity by $(t_p/t)^4$. And think there is mass missing!

Can log time explain 'Redshift'? Maybe.

- Imagine ray of light propagating in log time instead of linear time. It's phase would be $\phi = \vec{k} \cdot \vec{x} - \omega^* \tau$, where $\tau - = \ln t/t_o$.
- What frequency, say ω, would we measure sitting on earth if we thought time was linear?
- Frequency (in linear time space) is minus the time derivative of phase, so we would measure:

$$\omega = -\frac{d\phi}{dt} = \frac{\omega^*}{t} \tag{16}$$

- The farther the light has traveled, the bigger t, and the lower the frequency we observe. So we would think the rest of the universe is moving away from us.
- The implication is that the universe might appear to be expanding even if it is not! If it is not, we probably don't need 'Dark Energy' either.

Summary

- There is an accompanying paper "Could time be logarithmic?" Both it and this presentation can be downloaded from http://www.turbulence-online.com.
- Maxwell's equations, the virial equation, and special relativity seem to behave quite nicely.
- Our concept of the constancy of the speed of light probably needs to change – it is constant in log time variables. But we would not notice the difference except when we look back far in time.
- I've also tried to examine what happens if space itself is expanding along with logarithmic time.
- Hopefully I have given all the young people lots of exciting things to argue about. :-)