DRAFT April 7, 2016

Objective Time: What Time is

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Abstract

We define a level of abstraction beyond typical units of measurement allowing abstract measurements to be incorporated within the context of a model. The approach is applied to the concept of time resulting in a radically different perspective of what time is and what it does. The results show consistency with modern views of time via derivations of Lorentz's time dilation, length contraction and coordinate transformations.

Keywords: relativity, speed of light, cosmic inflation, big bang, objective relativity, abstract rulers

If you ask a physicist "what is time?" you may get lots of information but you won't get a very satisfying answer [18]. If you were to summarize their responses you might end up with something like "I wish I knew, but I don't. I can only tell you that time is what a clock measures."[11, 26]. But how is it that, if a physicist doesn't know exactly what time is, how would a physicist know that a clock measures time? Or more concisely, how do you verify that a clock measures time? Or simpler yet – how do you measure anything?

We typically think of measuring a length as a process of discovery. That is, when there is some length of interest we get out a meter stick and "discover" how long the target of interest is by counting the number of whole and/or fractional units of a reference length are required to equal the target length. Once we have assembled this number we express it as a product of a number and the unit we used to measure it with. E.g., 3m, or 3 meters. Where the label "meter" is an indirect reference to a well defined length. That is, "meter" is not just a label or a unit, its a length. Though most researchers think of a measurement result as a unitful number rather than the product of a scalar and a reference length. But let's look at this...

Let's express a measurement as a quotient like so:

$$scalar=\frac{target}{reference}$$

then as a product:

$$(scalar)(reference)=target$$

We can think of this expression as an *encoding* of an observable into a mathematical form, where the product, *(scalar)(reference),* is a reference,via the equals sign to an objective length or target. This separation of the physical from the abstract gives us a way of anchoring our abstractions to observables in a very clear and concise way. The abstraction is on the left hand side of the equals sign and the observable (virtual observable) is on the right hand side. That is, the meaning of the abstraction comes from the observable that the abstraction refers to. And since the abstraction has this objective anchor, this model for measuring length is intrinsically objective. The number π is a good example of this objective notion. Let's write this as :

$$\pi=\frac{circumference}{diameter}$$

or $$\pi(diameter)=circumference$$

Note that this applies to any circle where π is expressed in the unit "diameter" rather than a unit [L]. That is, while the unit is abstract it still refers to a well defined observable – the diameter. And the scalar π tells us explicitly how many diameters it takes to equal 1 circumference of 1 circle. I.e., the diameter is a reference length in the same way that a meter is.

(Computer scientists think of a reference as something to ultimately be "de-referenced" [15]. Where the term "de-reference" is an action that removes the reference to something and replaces the reference with the object of the reference. In the context of physical theory, the reference "meter" we carry around in our equations allows us to check the units we began a calculation with against the units we end up with. And we maintain this "unit", rather than de-reference it for the same reasons we don't want to "de-reference" the word "dog" when we only want to discuss a dog. That is, you don't really want to put an actual dog in a sentence. Ok... I am assuming that you don't :))

Many of us have worked though problems by applying dimensional analysis, where we have units like [L], [T] or [M]. What we're looking at here is quite different. That is, when you understand that *meaning* or *physical significance*, comes from the object referenced by its label then you can apply this "semantic grounding" [1,2,3] as a principle to be applied to any observable you like. E.g., since "dog" refers to a particular kind of mammal – an observable - it has meaning whereas "smarkulot" (a random string of letters) does not. This is the defining characteristic of objective physics. i.e., it does not rely on theory (guessing at the truth).

So now we can try out this new principle on the words "static" and "dynamic". If these are physically meaningful abstractions, what do they refer to? Is "static" a state or is it a relationship? Does it depend on other concepts, observables or conditions? That is, how do we go about making these words explicitly objective? Ans: by choosing a reference static. Intuition tells us that we should find something that is truly static – like a ruler. Then we can use our ruler to compare other things with to tell if they are static with respect to our discovered static ruler. But this intuition is wrong for one very good reason. We don't have prior knowledge [12] of what the string of symbols s-t-a-t-i-c means. Clearly matter is static with respect to matter, and as an assertion is irrefutable whereas the statement "matter is static" is questionable.

So if we don't know what the word "static" refers to, what do we choose for a reference static? Ans: Anything we can observe. Let's say we choose two electrons as the endpoints for our static reference length. Or let's say we choose two galaxies. Either choice is objective via the principle of semantic grounding. It also generalized the concepts of 'unit' and of 'length'. But to say that two negatively charged particles define a static length sounds absurd. And it seems this way because what we have learned since the electron was discovered in 1897 [4,5] is that particles with the same charge accelerate away from each other. It's tempting to conclude that this idea of semantic grounding must to be wrong! On the other hand, we might realize that electrons move away from each other with respect to our mater-like reference objects. In other words, it is our matter-like reference objects that we have defined by default assumption as defining our static reference objects. That is, without knowing it, we assume that the word "static" has intrinsic meaning and the same goes for the word "dynamic" [3,4]. We can say that not only can a physicist assign variables to observables, we can also assign English words and concepts to observables (i.e., give stuff names). And here we are defining the word "static" as an abstract reference to some line like object that we can observe. i.e., "static" is a variable but in the context of written language.

So how to apply this to "time". If we can't observe time, how can we make "time" objective? Easy. The observation we need is in our solar orbit. That is, every clock on our planet is an indirect reference to the position of the Earth in its solar orbit. And the Earth is in inertial motion[1] around the sun. I.e., the Earth changes position as the hands, or digits of your clock change. And because of this we

Illustration 1: The two red lines are static with respect to each other but are growing with respect to stable matter.

can, through this indirection, define the Earth's changing position as our reference dynamic. In other words, a clock doesn't measure time, it provides us with something that changes with respect to a reference static (matter). And it is that which allows us to use a clock to as a reference change to measure a magnitude of change. One powerful consequence is that, by extension, we can apply this idea to define a reference speed for measuring other speeds and a reference acceleration for measuring other accelerations (and more derivatives if we want) and then apply our model to measure speed with a reference speed. And all of this is to say that if we can use a reference length to measure other lengths we can just as well use a reference speed to measure other speeds.

Take Illus. 1 as an example. We have two lines, each defined by two distinguishable end points. *Line a* is defined by a rifle and a bullet and *Line b* is defined by a pistol and the bullet it shot. If we apply the above principle of semantic grounding we can say that *Line a* and *Line b* are static with respect to each other. But, because the two lengths are growing are also dynamic with respect to a matter-like reference. We can also say that, if we choose *Line a* as our reference static that matter is shrinking with respect to *Line a*. So rather than

1 For now, our classical understanding of "inertial motion" will serve as a placeholder concept since an objective understanding of inertia is beyond the scope of this paper..

expressing a speed in the units m/s or [L]/[T], we can define an equivalent unit like [V] where the unit [V] = [Target Speed]/[Reference Speed] which is also equivalent to [V] = [L]/[T]. Or just like before :

$$scalar = \frac{target}{reference}$$

where *target* is static with respect to *reference* and this static relationship is independent of other dynamic relationships. E.g., *reference* can represent a reference speed, acceleration, jerk, snap, crackle or pop etc. Note also that If you're deciding between a Euclidean or a non-euclidean reference length, the choice is easy. Choose Euclidean because *a measurement is a mapping or an encoding* of an observable into a real number. Or to put this another way, why choose the more complex (non-euclidean) when the simpler will do just as well?

So now lets do a bit of simple math. Let's prove that special relativity is a consequence of all that we've said so far.

Iillusration 2 represents a clock in motion where *v* and *t* are static with respect to each other and also *linearly independent* of one another. Both are speeds where we assign *t* the role of reference speed and *v* the target speed or the speed at which the clock is moving with respect to *t.* And while the quotient *v/t* represents the measurement result of interest we can also look at the solution of this triangle where we define *v* as the independent variable and t the dependent variable. And we'll assign *h* the role of reference length.

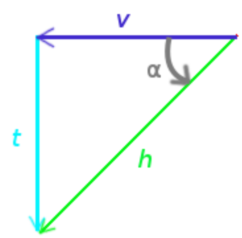

Illustration 2

Then, because *v* and *t* are *linearly independent* (not perpendicular) of one another we have $\frac{t}{h} = \sin(\alpha) = \sqrt{1 - \frac{v^2}{h^2}}$ And since h is our reference “length” we assign it a value of 1. Which gives us:

$$t = \sqrt{1 - v^2} \quad (1)$$

All by itself this says:

1. The reference t , gets smaller as v increases in exactly the same way as time does in special relativity.
2. Time is not required.
3. An additional frame is not required.
4. This relationship is independent any observer or the speed of light.
5. No assumption about prior physical law.
6. Acceleration, jerk, snap etc. are all relative.
7. Implies a maximum acceleration, jerk, snap etc.

If we add a second velocity as measured by a second clock we add subscripts 0 and 1 to refer to the two different frames. Then we have: $t_0 = \sqrt{1 - v_0^2}$ and $t_1 = \sqrt{1 - v_1^2}$ where $v_0 \neq v_1$.

If we want to know how much “faster” or slower clock 1 is with respect to clock 0 is we measure t_0 with t_1 :

$\frac{t_0}{t_1} = \frac{\sqrt{1 - v_0^2}}{\sqrt{1 - v_1^2}}$ Then choosing the frame containing

$t_{1,} v_1$ as the frame at rest we set $v_1 = 0$, then:

$t_0 = t_1 \sqrt{1 - v_0^2}$ in natural units [6] and:

$t_0 = t_1 \sqrt{1 - \frac{v_0^2}{c^2}}$ in SI units[2]. Then to convert from SI units of "time" to units of length we multiply by a conversion constant "c" to get :

$t_0 c = t_1 c \sqrt{1 - \frac{v_0^2}{c^2}}$ giving us: $l_0 = l_1 \sqrt{1 - \frac{v_0^2}{c^2}}$ That is, when we make our "velocity" variable unitful we need to return it to its natural or unitless or abstract unit form via the conversion constant c.

So let's apply this to Galileo's transform, $x' = x - vt$ Then, since the difference $x - vt$ is a length we apply our length contraction to it to get:

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad (2)$$

then converting Galileo's transform to the units of time (which is really a reference change in position) we have:

$\frac{x'}{c} = \frac{x}{c} - \frac{vt}{c}$ and via our conversion constant $\frac{x'}{c} = t'$ and $\frac{x}{c} = t$ we have: $t' = t - \frac{vx}{c^2}$

Then, since the difference $t - \frac{vx}{c^2}$ is also a length we apply our equation for time contraction (yes contraction as opposed to dilation.)

$$t' = \frac{t - \frac{vx}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad (3)$$

Questions

So, Objective time is indistinguishable from the best theory of time to date. But is it in fact objective ? Playing devils advocate here are some questions I've come up with.

Q: I don't quite understand how something in motion is equivalent to a clock.

A: There are two parts necessary to define a working clock. Something that's static and something else that changes with respect to said static object. Think of a bead moving at some inertial velocity along a frictionless wire in deep intergalactic space where there is a very long (light years long if you like) reference length parallel to the wire. And where the reference length is marked off in well spaced hash marks. Let's say that the hash marks are separated by 10E-100 meters. The bead and wire define a classical clock. And can be used in the usual ways to measure the speeds of other objects. Now, let's also say you have two American astronauts nearby moving at inertial speed away from each other. (Just ignore their bickering over who is actually the one in motion.) Lets define them as the end points of a line like object. And lets also say you have two Canadian gnomes nearby. Where they too are moving away from each other at inertial speed.

2 There are details related to unit conversion that I've intentionally omitted because they lead into the question "Is a unit of length of space equal to a unit of length of matter?". Another lengthy topic :)

Lets call them “gnome boys” and “astro boys”. They too define the end points of a line. These two distances are growing with respect to ordinary matter but not with respect to each other. i.e., with respect to each other and only with respect to each other, they are static. Now place copies of our well marked reference length along the lengths defined by the gnome-boys and the astro-boys. And give each of them a can of spray paint so they can paint colored lines on their respective reference lengths. What you'll observe is that while the painted lines increase in length the ratio of their lengths remains constant. And this ratio is identical to the ratio of the lines sans static reference length. And because of this equivalence, we can measure the speed of something with a reference speed. Where the two speeds of interest are line-like. (see Illus 1 and accompanying discussion.). It might also help to have a look at this animation[26]. The gist of this is, you don't need a classical clock to measure a speed. And even if you do use a classical clock it is still an indirect reference to the orbital dynamics of the Earth around the sun. i.e., a reference speed. Yes, even an atomic digital ticking clock.

Its worth mentioning that this example explicitly omits a start time or end time to show that we still get a measured speed that is indistinguishable from a classical speed and we do so by replacing “time” with “reference speed”.

Q: Most physicists think of time as something that is regular, something that repeats. What is it, in your model that repeats?

A: Hash marks. In the above example, as the bead moves it crosses evenly spaced hash marks. Remember, we encode what we observe in a way that makes our abstractions useful and easy to work with. The hash marks are something we introduce for practical reasons. If you think about it, you might see how to devise a clock that ticked as it crossed each hash mark. It's important to realize that our devices are useful to us and are based on what the universe is and does. When we can remove the mechanics of man made clocks we can actually understand what's going on with natural time.

Q: If your model of a measurement is a quotient, don't you get infinities for reference lengths of zero units of length?

A: Yes. But getting lengths of zero is very difficult. Impossible really. First, nobody will ever choose a point as a reference length. And if you don't choose a reference length of zero you can still get a length of zero in other rulers if your speed *equals* the speed of light. Note that Eq. 1. can be misleading if you think about it in terms of numbers. That is, Eq. 1 seems to say that t shrinks as v increases. And that's not true. What happens is that t becomes *relatively* small with respect to an increasing v. t is not actually shrinking, or at least the question of whether t is shrinking or v is increasing is actually indeterminate. Say for example you have a black box and in it is a reference length and a target length and on the outside is a button and a display of the measurement result. You push a button to repeat the measurement. The first time you get a measurement of 10 units the second time you press the button you get a reading of 20 units. Did the reference length change or did the target?

Q: Wait! If you can't tell if something is growing or something else is shrinking, doesn't that contradict the big bang? It sounds like it is ok to say that the universe is static and our matter-like reference objects are shrinking. Yes?

A: Yes. To say that the universe is expanding is just another way of saying that matter is shrinking. These are just two different ways of saying the same thing. But it does bring into question the veracity of a beginning of the universe. Since the cosmic time that the big bang depends on vanishes. And Eq's 2 and 3 tell us there is a speed limit in the universe and it may not be broken even in principle. And this is a serious problem for Cosmic Inflation. Inflation [23] took about $10^{-33} s$ where the universe increased in size by a factor of about 10^{26} . Inflation ignores the fact that the units of length and time do depend on physical objects. Cosmologists argue that this is ok since the inflationary expansion occurred in both space and time so it doesn't actually break the speed of light limit. But the simple statement “It took 10^{-33} seconds for one meter to grow to 10^{26} meters.” is an impossible statement in the absence of something that defines a physical meter and a second. It is also impossible since this is a velocity of about 10 $10^{59} m/s$. A factor of about 10^{7} times the speed of light. Big Bang expansion relies on “metric expansion” where spacetime expands in a way that does not break the speed of light. That is, the contents of the universe don't actually move with respect to spacetime, but the distance between them increases during expansion. In otherwords, until cosmologists can address the issue of “static reference length” it's questionable that inflation is possible.

Q: So if I can choose any two points in the universe as a static reference length, then I can choose the end points of an oscillating spring. Wouldn't that mean that the universe is oscillating?

A: Yes, with respect to your chosen reference static. Remember, you are encoding observables into numbers. Its a choice you make to make a model easier to work with. We construct abstractions so that we can do virtual experiments for one very obvious reason; its easier to do the math than actually do physical experiments. So construct the abstract tools that make your abstract experiments easy. If an oscillating/static reference makes your virtual experiments easier then that's what you should choose. But because there are other non-trivial factors that are related to the mechanics of a spring that might be troublesome, you might want to rethink the “spring” idea. That is, because there are other deeper phenomena that give a spring its oscillating properties a spring might not be a good choice for fundamental physics.

Q: Why is the speed of light so big?

A: Its big because of the unit of time or distance we have chosen. Think of measuring driving distances in millimeters. A drive of 300 miles isn't that big. But if you chose to represent that in millimeters it would be 482803200 mm.

For most physicists the speed of light is just 1 unit of space per unit of time [6]. And in the context of this paper this is equivalent to saying that the speed of light is 1 Fmoco, where 1 Fmoco is one unit of reference speed.

Q: It sounds like you're saying that $D=\sqrt{(x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2}$ is wrong.

A: No. Pythagoras's distance formula works fine if you're only dealing with distances that are static with respect to you. And since you're made of matter, then we're implying that it only works for matter. Which begs the question "is a unit of length of space equal to a unit of length of matter?" (A question to be addressed eventually.)

But, here's what you need to see. When you verify a distance, velocity or time predicted by a theory you wouldn't measure distances along some set of axis. Or at least I hope you wouldn't. It introduces parasitic measurement errors in distances and angles. Using only a quotient to represent a measurement result seems to be the best way to represent how we actually verify a theoretical prediction.

Q: If anything can move in any direction, doesn't this violate "The Arrow Of Time"?

A: The "Arrow Of Time" is based on the 2nd law of thermodynamics which says that in an *isolated system* entropy tends to increase over time. [9] E.g., a copper penny dissolved in nitric acid never regains it's shape, a broken glass never "un-breaks". Thermodynamic systems are systems of change and so they too need a reference change to determine a magnitude of change. And so for a thermodynamic system, it is the system with the large object count that is "time" dependent – not the other way around. We could say that because the thermodynamic arrow of time is one directional then so must be time's arrow. But, in a classical context, this just hides one abstraction in another. It is far clearer to realize that to move from one point to another with respect to some static frame of reference (say a table top) the distance between its starting point to where it moves to can only be positive. For example, draw line on a piece of paper and notice that the line never has a negative distance.

I should also point out that physics is the art of reduction. Thermodynamic systems are not "reduced systems".

Q: So if you're saying that time is not an orthogonal dimension, is Einstein's General theory of relativity wrong?

A: No. Einstein began GR with a classical notion of time and then applied special relativity to it "as is". It worked well because he implicitly combined space and time. That is, classical time does not imply anything space-like either as an orthogonal or embedded dimension. The classical "elements" of time that Einstein used imply order but without a concept of separation. And a space-like separation is impossible to define when there is no past or present. i.e., without a time-like ruler we can't verify the distance between "times". Einstein's theory worked well because he added in a fourth dimension that had the needed space-like character. But it was put in by hand because he believed time was an un-observable fourth orthogonal dimension.

Q: If I look at my watch at one o'clock and then at two o'clock, isn't that a time-like separation of 1 hour?

A: Of course that works fine in a practical sense, but you are implicitly relying on two or more other references. The first is the sun. Your watch is calibrated by the motion of the Earth-Sun system. The second is your own internal clock that provides a reference change. There are many sources of "internal change" that can serve as a clock. Exactly how your body gives you a sense of time isn't all that clear [24] and is certainly not fundamental. But even so, it's not a clock that you can turn over to somebody else for verification. I.e., its not objective.

Q: If I find the quotient of 4 meters divided by 2 meters I get a unitless 2. Not 2 meters. What happened to the units?

A: Yes that's right in your case the units vanish. But you're finding the quotient of two measurement *results* not the quotient of two lengths. Remember that the word "meter" is a reference to a well defined object that is line like. We don't actually have prior knowledge [12] of how long a meter is. Ask yourself "how long is a line?" or ½ of a line? A meter stick is line-like. By comparing it to other line like objects we can tell how much larger or smaller other line like objects are with respect to the length we call a meter. The same goes for speeds and reference speeds.

Q: There is a distinct pattern in physics. With each new foundational truth, theory becomes more and more interdependent on these new findings and as a result tends to increase in complexity. You have created something simpler, rather than more complex. I mean... Aren't you heading in the wrong direction?

A: Physics is the art of reduction. But we have to pay attention to what it is that we are reducing as well as how we reduce. Its not just reducing observables to the point where we have our immutable atoms. It is also a program of reducing our concepts and symbols where we have an unambiguous 1:1 semantic alignment of symbol and object. And it is this point that we need to aim for since any other relationship leads to confusion and ambiguity. E.g. Quantum Entanglement [19], Wave Particle Duality[20], Big Bang Cosmology[21], Heisenberg uncertainty[22], Decoherence[23] etc. Objecitive relativity takes us "back to the drawing board" to re-examine and refine our concept of time so that we can start over and possibly go beyond Einstein.

Q: In illus 3. how can you justify that *t* is not orthogonal to 3-space?

A: Occam's razor. I've never seen "a time" but I have seen things move. If a phenomena is observable and reproducible you don't have to construct a complex argument for what you observe. Because of this, objectivity trumps theory. If it were otherwise we would never need to verify a theory. Objective time is both observable and is the simpler explanation for length contraction and time dilation.

Q: Why should I believe you?

A: You shouldn't. That's the the point of Objective Physics. If I give you two objects you can compare them just like I can and determine if they are alike or not, relatively larger or smaller than one another etc.. There is no argument required. The comparision – if well defined - is reproducible and does not depend on what I have imagined to be true.

Life gives us our sense of the universe through our senses. And we take this information as authoritative. Our eyes have built in reference lengths and speeds in our rods and cones [16,17] that allow us to perceive the world in two, three and "four" dimensions. In our day to day experience, if we did not take the information given to us through our senses as authoritative we might not duck when we see a rock thrown at our heads. Consider not doing so. E.g.,, an alternative to ducking might be collaborating with a colleague on the subject of "Is that a rock coming at my head or is my head moving towards the rock?" And this is to say that we do take our senses as authoritative (or intuitive!) to survive, but we shouldn't be dogmatic about it. We are free,in fact, to challenge our perceptions and intuitions as well as others. Objective physics takes us a step in that direction by defining *external* reference objects in a general way so that subjective experience via our senses does not cloud the objective truth with intuition, opinions, guesses or authority.

Conclusions

From here the derivations of special [6] and general relativity [7,14] can be built in exactly the same way as Einstein built them. But, more intriguing, if time is really just a reference change in position, then Einstein's 4-dimensional universe overlooked a few other dimensions. That is, given that a reference speed may take any direction in a space of three orthogonal dimensions, we can add 2 more embedded "time-like" dimensions and infinitely many other multiples of three dimensions to build entirely new models of the universe. In other words, Einstein's general relativity as it is, is incomplete. And any theory that accepts Einstein's general relativity inherits that incompleteness.

Summary

Each of us has a built in clock that gives us a sense of the passage of time. As well as a sense of the past, present and future. And it is this subjective sense that has whispered to us "a clock measures time" or "a clock is something that cycles", or "time is a flow" ...etc. Our intuitive sense of time works well in a practical sense but fails us when we seriously consider the question "What is Time?" and/or "How Does Time Work?". For more than 100 years, state of the art physics tells us that a length contracts when it moves fast because the speed of light is constant with respect to all frames of reference. Or, conversely, the speed of light is constant with respect to all frames of reference because clocks and rulers conspire to maintain the constancy of c, via length contraction and time dilation. Its a circular argument. Here, where we define a model of a measurement of length, speed and acceleration we see how we can break this circle in an entirely objective way.

Time as an orthogonal dimension simply goes away when we apply Occam's razor [9]. Occam's razor basically asks something like "well.... what would you rather do? Drive 100 times around the block and then drive to the store or just drive to the store?" In other words why choose the more complex choice over the simpler when they both give you the same result.

With time as a reference change, there are lots of very new ways of thinking about physics that underlie the observable universe. Many of them turn out to be surprisingly simple. But probably the most exciting result of objective physics is how soundly it lays to rest misunderstandings of the concepts of time we've held for centuries.

A few implied questions

With an observer free theory of relativity, might it be possible to apply the same principle to create an observer free quantum mechanics?

If we can view cosmic expansion as a relative expansion, can we view the universe as static and matter as shrinking?

Is a unit of matter-like length equal to a unit length of space?

With this idea of an abstract clock, can we determine the clock speed of arbitrary objects? A hydrogen atom for example?

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