Does Conway's "Game of Life" predict that the speed of light is constant in the real world?

"Gathering 4 Gardner 14" presentation

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James D. Weinrich

jimwsandiego@gmail.com

jweinric@sdsu.edu

619-920-8332

The kind of feedback I need: Please tell me whether these ideas are (1) wrong, (2) true but trivial, (3) good for explaining concepts in textbooks, (4) new and novel but not very important, or (5) new, novel and important. Thank you!

Abstract

Conway's Game of Life needs no introduction to fans of Martin Gardner.

Numerous examples exist in which a GoL "spaceship" object sends out smaller objects ("gliders", etc.) that move away from the generator at a constant speed. That speed is set by the underlying nature of the GoL's generations, because each such object can move no faster -- generation to generation -- than the unit distance built into the GoL model itself. In fact, the maximum such speed of propagation is called *c* or "the speed of light" in GoL terminology.

In a typical computer running a GoL in a lab, the unit of time in the GoL of course has no fixed relationship to the unit of time marked on the lab's clock on the wall. If the lab personnel were to double the rate of GoL generations (relative to the clock on the wall), the speed at which a GoL glider moves across the screen is also doubled (relative to that clock), but within the GoL universe itself, there is no change in speed.

Might this phenomenon actually apply in the real world of spacetime, and its actual speed of light?

The very concept of spacetime encourages us to think of time as a literal dimension. If so, what is the multiplier used to convert units of time to units of distance? The natural conversion factor would be to set the unit of time to be the Planck time, and to set the unit of distance to be the Planck distance; the conversion factor would be the speed of light.

Now imagine that the universe is the surface of some hypervolume, which is expanding -- being laid down -- along the time dimension. The "future" is akin to some kind of gas: an energy field with no structure or organization. The "past" is akin to a solid structure that has previously condensed out of the gas. The "present" is the condensing layer between this past and the future. The present is a layer of spacetime, which contains matter in particular positions. The layer also has waves that can transmit energy by moving in the various spatial directions.

A single assumption leads to the prediction that the speed of light in the real universe is a constant, just as it is in the GoL. The assumption is that a particle in layer *t* (for present time), at position coordinate X (in any given spatial dimension) can at time *t* + 1 be positioned at X, X – 1, or X + 1. A bit of the energy from the future "gas" can condense into the layer of the present moment only by latching onto a particle in the Present layer that is positioned at, or next to, the point at which the condensation occurs.

If we were to imagine that this hypervolume exists in some uber-being's computer lab, for those of us living in the hypervolume, it doesn't matter how fast the Planck-thickness layers accumulate.

If light is something that undulates on the surface of this expanding spacetime solid, then it can propagate through space no faster than it can move from layer to layer of time. Each additional time layer permits no more than one Planck step in any spatial direction. Regardless of whether we regard light as a wave or as a particle, its angle through spacetime can never be more than 45° away from the path of a stationary object.

Finally, the model sheds light on the wave-particle duality nature of matter and energy. A "particle" is a kink in the outermost layer of spacetime that stays in place, or moves one unit away, as waves and events in the condensing layer progress. In the condensing fluid, such a kink is a wave; once condensed, it's a particle whose location can be known to within a Planck length.

Introduction

For several years, the consensus of astronomers has been that the universe is, in the present era, expanding at an accelerating rate. This consensus was based on well-founded empirical data that seemed to compel such a conclusion. A report by Milne et al. (2015) concluded that the universe's expansion is slower than this previous consensus suggested. If this revised conclusion is correct, then now may be a good time to consider models that feature or require a constant rate of expansion of the universe.

If a universe expanding with zero acceleration is indeed consistent with observation, then some simple postulates about the nature of time and the fabric of spacetime lead to answers to two commonly-asked questions: (1) Why is the speed of light a constant? and (2) Why can nothing travel faster than the speed of light (or, as will be argued, the speed of gravitational waves)? This paper explores an extremely simple model of an expanding universe that straightforwardly yields answers to these two questions.

As it happens, John Conway's Game of Life (GoL) also has a maximum travel speed—for reasons that are very similar to the reasons proposed in this paper for the real world. The purpose of this paper is to set out this theory of the universe, and use the GoL as an illustration of many of its principles.

This model has several fundamental predictions. It suggests why time is the physical parameter that we can measure with the greatest degree of accuracy, and explains how the forward arrow of time is inextricably linked to the expansion of the universe, why the rate of expansion seems to be exactly what is needed to avoid collapse, why spacetime is so exceedingly geometrically flat (without needing to postulate a special mechanism for a period of hyperinflation), and why light cannot complete a circumnavigation of the universe. Moreover, the model predicts that the universe is prevented from collapsing back into a singularity by virtue of a mechanism that would emerge in equations as a parameter related to dark energy. Finally, it explains a fundamental difference between hadrons and bosons, and may incidentally explain why matter predominated over antimatter in the early universe.

John Conway's "Game of Life"

There is an earthly universe in which there is a maximum speed of travel—a speed that follows from the laws that underlie the passage of time in that universe. That is John Conway's Game of Life. In a GoL universe, each particle at any given point in time contributes to the creation of a particle at adjacent points in the next point in time. GoL fans are familiar with arrays of points that generate, and/or propagate, so-called gliders that (when animated) move through GoL space at a fixed maximum speed. No GoL object can travel faster than this, because the particles that make up the glider at time t can only influence slots in GoL space at time t + 1 that are one pixel away from it at time t. Indeed, this speed, in GoL terminology, is called the "speed of light".

The purpose of the present paper is to explore a model of the expanding universe that has a maximum speed that is almost perfectly analogous to this mechanism. Nothing can travel faster than the speed of light in our universe because each moment in time is a layer in an expanding universe, and each bit of matter in layer t of that universe can move no more than one layer's worth away in layer $t + 1$.

The Postulates

The theory follows logically from a small number of postulates about the nature of spacetime. Many of these have been previously posited (and long ago) by other scientists. However, one key postulate (number 4) appears to be novel. In combination with the others (especially postulate 5), it explains the constancy and the maximality of the speed of light.

• Postulate 1: Space and time are inextricably united in a fabric-like substance called spacetime

This is, of course, the point of view of Einstein's special theory, Minkowski space, and the Lorenz transformation equations, and needs no elaboration here. Spacetime's fabric-like nature is likewise widely appreciated.

• Postulate 2: The time dimension is exactly like the spatial dimensions, yet is different

This is also generally appreciated, but a certain aspect of it needs emphasis. Like many others, the proposed theory presumes that spacetime is a real thing—not merely a useful analogy—and that the time dimension is in some ways exactly like the space dimensions in a deep, tangible, and probably literal way.

To fully appreciate the model, the units used to measure space and time should be identical. But this principle (also a familiar one) goes beyond the use of a distance measure such as light-years. One ought to be able to say either that "the ball moved 300,000 km to the north" or "the ball moved one sec to the north". Likewise, one should be able to state that a ball that appears to us to be at rest in space either "moved 1 sec into the future" or "moved 300,000 km into the future".

This postulate is scarcely controversial in and of itself. The key is that it encourages us to equate (in Postulate 4) the speed of light moving through space with the speed of objects moving through time.

- Postulate 3: Planck distances and Planck times have a fundamental reality

Something fundamentally important (and very strange, from the point of view of our limited experience of the macroscopic world) takes place at Planck times and Planck distances. The time it takes light to travel a Planck distance is a Planck time (in accord with Postulate 2). If there is any granularity, quantization, or fundamental minimum distance in the structure of space (and by extension, the measurement of location), there is an equivalent granularity, quantization, or fundamental minimum time—and vice versa. If space and time are one, then so are Planck distances and Planck times.

- Postulate 4: The expansion of the universe is—***is***—the progression of time, and thus must always be experienced as constant by objects in spacetime

This is the key assumption. Like sheets of paper accumulating into a ream, like acetate cels piling up to create an animation or flipbook, like a mineral seed planted in a hypersaturated medium growing into a crystal, like a blob of gelatin slowly solidifying as it cools into a bigger blob of gelatin, like a layer of living coral (on the surface of a growing ocean floor) that builds its present life on its dead calcium skeleton below the surface, the expansion of the universe into the time dimension *is* time. The universe as we experience it consists of the outermost Planck layer of that crystallized product, a layer that is constantly changing as it grows. The passage of time is the experience of motion in the direction of the time axis, with objects as we experience them at each moment existing only in that Planck-thickness layer. The universe expands by accumulating layers, each of one Planck time/distance in thickness.

Someone at rest in our universe, but by necessity moving along the time axis, can observe and measure oscillations in local objects; we call those oscillations “time”. If someone moves along a space dimension (also through time), they travel on a diagonal path through spacetime, but they will still observe and can measure oscillations that they will experience as “time”. And as far as they are concerned in their frame of reference, their gelatin-surface world is still growing (i.e., moving through time) layer by layer, with each layer being just as thin and Planck-like as any other. Thus, an object moving along a diagonal spacetime path is experiencing the expansion of the universe at the same constant rate as everyone else.

In this view, it is impossible (nonsensical, actually) to observe that the universe is expanding at an accelerating rate. Imagine being a cartoon character who exists by virtue of being a drawing on an acetate cel, and imagine a clock on the wall of that character’s environment. The godlike creatures that produce the cels, stack them, and flip through them to create an animation can produce each cel on their own schedule in what might provocatively be called godtime. It is irrelevant how long it takes for these powerful creatures to draw each cel, and it doesn't matter how quickly the flipbook's pages are flipped in godtime; as far as the residents of the tooniverse can tell, a clock on their wall ticks at a constant rate.

Of course, there is no need to invoke a godlike animator. John Conway's Game of Life is an example of an automatic evolution-like unfolding of a series of animation-like snapshots that resembles a growing, moving organism when animated (and which is limited in the way about to be proposed in Postulate 5).

The analogy to animation cels (or an accumulating ream of paper) presumes that each layer is distinct from the previous layer, and from the next layer across different spatial locations. To the contrary, perhaps the accumulation is more like the condensation of what might be called a gelatin crystal, in which it is not clear exactly which molecules in the past constitute a given layer. In this case, an entity on the surface can move diagonally through gelatin spacetime, and experience its own, somewhat different, set of layers.

- Postulate 5: From time t to time $t + 1$, measured in units of Planck time, matter and energy can move no more than one Planck length in any direction

This is the other postulate that has been overlooked, although many scholars presume nearly the same thing when they assume that c should be the conversion factor between units of time and units of length.

As layer t + 1 is about to be deposited on top of layer t, a bit of matter-energy in layer t, at spacetime coordinates (x, y, z, t), can move no more than one Planck length in any spatial dimension as the next layer of Planck time is deposited. That is, something at (x, y, z, t) can move or copy itself into the region [x ± 1, y ± 1, z ± 1, t + 1]—and no further. (As mentioned above, this situation is mirrored in Conway's Game of Life.) If a particle, for example, were to move two or more Planck lengths away between times t and t + 1, it couldn't be the same particle. Likewise, if a wave (or other disturbance) on the surface of the expanding universe were to move two or more Planck lengths away between times t and t + 1, it wouldn't be perceived as the same wave. Matter and energy at one point in time directly *and locally* cause the arrangement of the next layer of time.

- Postulate 6: Bosons are constantly moving waves in the fabric of spacetime

Gravitational waves may be (or, arguably by definition, are) waves in the fabric of spacetime. If so, they must propagate at the same speed in space as the expansion of the universe does in time. Einstein seriously considered (and then lost interest in, for reasons that are unclear) the notion that light is also some kind of undulation in the fabric of spacetime (Einstein, 1920), even going so far as to use the word "ether" in connection with that fabric. Of course, the idea of a luminiferous ether is inconsistent with observation, but those famous observations pertain to the hypothesis that "ether" is a substance that exists *in* spacetime. To the extent that Einstein's theory (and the present theory) include a concept that resembles ether, it is not *in* spacetime: it *is* spacetime.

Instead of saying that the speed of light is a speed limit for everything in the universe, it would be more primary to declare that the speed limit is the speed of gravitational waves. Logically speaking, the insight that nothing travels faster than the speed of light is secondary to the insight that nothing travels faster than the propagation of gravitational waves. It follows trivially that light does not travel faster than that speed.

However, there is a sense in which objects *can* travel at the speed of light—and always do. An object may be at rest in the three dimensions of space, but that object is nevertheless traveling through spacetime. Indeed, the point of view of the present theory is that all objects travel through time, literally, at the speed of light.

At the risk of being overly epigrammatic, it might be said that space travels through time at the speed of light, and light travels through space at the speed of time. These are merely restatements of the postulate that space and time must be measured with the same units.

• Postulate 7: Hadrons are movable, semi-stable structures in the fabric of spacetime

A simple knot loosely tied in a rope can be moved from point to point along the rope by inserting one's thumb into the loop of the knot, moving one's hand left or right, and allowing the rope to slip around the thumb (taking care to avoid pulling the knot tighter). Because the word "knot" has a very specific topological definition that is contrary to this lay concept of a knot, I will use the word "kink" to refer to the concept of a knot-like disturbance in the (otherwise) smooth hypersurface of the expanding universe. Although the present theory is agnostic on the question of the reality of strings, aficionados of string theory are welcome to think of kinks as being composed of vibrating strings.

Kinks can be inside or outside of the expanding surface of the fabric. On the outside, they are postulated to be matter; on the inside, they are antimatter. When they collide, they annihilate each other (by unkinking each other, symmetrically) and release the potential energy they had stored. By their nature, even when motionless, they disturb and distort what would otherwise be a perfectly smooth, expanding universal hypersphere. Perhaps this distortion (like that of a kink in a rope) is smoother when viewed from one side than the other.

When a kink moves, it carries this distortion with it. To the extent that this distortion occurs along the time dimension, a moving kink resembles a wave—albeit an irregular one, and one that does not have a tendency to propagate in all directions (as most waves, such as sound and light, do).

• Postulate 8: Gravity is the force that glues one layer of spacetime to the next, by virtue of its strength at Planck distances and in the time dimension

Gravity is often described as the weakest of the fundamental forces of nature, but gravity is not a weak force at Planck distances (Physics Stack Exchange, 2015). The other fundamental forces (electromagnetic, strong, and weak) behave according to equations that can operate only on the surface of expanding spacetime. Only gravity's equations permit it to exert force from one layer to another. The theory postulates that a particle (kink) that exists in layer t of the expanding hypersphere attracts condensation (of some sort, in some sense) in layer t + 1, and that the two particles are bonded to each other by the force of gravity otherwise operating outside of our awareness.

• Postulate 9: Hadrons and bosons are fundamentally dissimilar

According to Postulate 7, hadrons are particles, and are localized deformities (kinks) embedded in the surface of spacetime. Thus, when they move, they have some wavelike properties, but they are not fundamentally waves. Kinked, they contain potential energy. Unkinked, they release that energy, which can then be re-kinked or completely released as moving undulations.

In everyday experience, a fundamental property of what we call "particles" is that they can move or they can stand still. You can hold them in your hand, or you can throw them away. If they stop moving through time, they disappear; we say they are destroyed, or converted into pure energy.

How can you hold a moonbeam in your hand? You can't. Bosons, by virtue of their wavelike nature (Postulate 6), *must* move through space. If bosons stop moving, they disappear; we say they are absorbed. Moreover, applying the time dilation equations to bosons results in the conclusion that bosons do not experience the passing of time. Indeed, their motion across the hypersurface of the expanding universe does not leave any tracks, and in that sense they are timeless. Particles, on the other hand, leave a record of where they have been (see Postulate 10).

Again at the risk of appearing overly epigrammatic, note that hadrons must move through time but need not necessarily move through space, whereas bosons must move through space but do not experience the passing of time.

- Postulate 10: The universe began not with a big bang but with a little plop

The simplest hypothesis about the earliest moment in the history of the universe is that it began as something no larger than an entity of Planck-sized dimensions—a seed, if you will. (This is termed the Planck epoch.) The present theory imagines that the universe then expanded as a 4-dimensional hypersphere around this seed, and that (as previously mentioned) our experience of the universe consists of the 3-dimensional surface of that hypersphere combined with a perception of the passage of time. Each unit of matter on that surface attracts another unit of matter that "condenses", in a sense, from the formless energy soup of the surrounding future. One can think of this energy soup as a field: perhaps a Higgs field.

Like a special type of coral that lives and grows atop an expanding ocean floor, the universe's present state is displayed on the surface, and its history is recorded beneath the surface. The cosmos is, in this view, the surface of a kind of crystal—a solid (or at least non-fluid) structure that possesses a particular past and an uncertain future.

Whether this imagery can be converted into equations that can be tested against experiment is an exercise for the future.

Deductions

Accuracy of time measurement

If the progression of time is by its nature constant (Postulate 4), it might make sense that the measurement of time is the physical parameter that can be measured to the highest degree of precision. This seems to be the case. Lombardi (2002, figure 17.1) indicates, for example, that seconds can be measured to an accuracy of 10^{-15}, whereas the next most-precisely-measurable quantity is length (to 10^{-12}).

The rate of expansion appears to be precisely regulated

If the rate of expansion of the universe constitutes time, there need be no puzzlement about why the universe's expansion seems to be *precisely* what is needed to avoid eventual gravitational collapse. It also explains why the universe has not already expanded so quickly that stars could not have formed and entropy would be the universe's most obvious property. There is no need to invoke the anthropic principle or multiple universes—or godlike creatures.

Dark energy (but not necessarily dark matter?)

Dark energy is postulated as a force that causes matter to repel other matter, and thus counteracts what has been thought to be a natural tendency of the universe to contract as a result of gravitational attraction. In the present model, there is no need for such a specific force operating in the spatial dimensions. What keeps the universe expanding is the fact that the layer of the hypersphere created at time t + 1 rests, almost literally, on the layer created at time t. The matter in layer t triggers the condensation-like creation of layer t + 1. Layer t continues to exist forever. According to Postulate 8, gravity itself is the force that binds matter in each layer to matter in subsequent and preceding layers. The word “bind” correctly suggests an attraction, but the idea of a repulsion is implicit in it; two particles that are glued together cannot separate, but they also do not collapse into one.

If one were to write equations that describe this condensation/accretion process, dark energy might emerge as a parameter or variable that appears when such equations are restricted to the domain of the expanding hyperspherical surface.

Dark matter, on the other hand, does not specifically appear in the present theory. Whether or not it exists is not addressed by the theory. Either alternative is possible.

The predominance of matter over antimatter

If an inflated balloon is coated, inside and outside, by a layer of particles of uniform size, slightly more particles can be fitted onto the outside than the inside of the balloon. If spacetime has (or had) a positive curvature, might this account for the predominance of matter over antimatter? This deduction seems likely in the light of Postulate 7. If there was a time in the history of the universe when spacetime was positively curved, and if a highly energetic process generated kinks on the outside and inside of this hyperspherical surface up to their respective volumetric limits, somewhat more kinks would be created outside than inside. If, as the hypersphere grows and its contents cool, the indiscriminate generation of kinks were to cease, then those inside and outside of the surface would annihilate each other. The result would be a universe in which the “matter” kinks (outside) numerically exceed and destroy the “antimatter” kinks (inside)—but only by a small percentage.

Photons are their own antiparticles

Besides being a known fact, this follows from the nature of waves. If a photon is an undulation on the surface of the expanding hypersphere, then its antiphoton would be an undulation of exactly the same wavelength and amplitude, but of opposite sign: undulating out when its photon is undulating in, and vice versa. By the nature of waves, this is just another undulation: one that is 180° out of phase with the original.

Photons move forward and backward in time—just a bit

Sound is a wave whose undulations take place in the direction of the sound’s motion. A vibrating rope is a wave whose undulations take place in spatial dimensions perpendicular to the direction of the wave's motion. In what direction do light waves undulate?

The displacements of the undulations of a propagating light wave are in the direction of advancing time—i.e., minuscule hills and valleys wrinkling and moving across the hyperspherical surface. In a sense, then, every wave of light moves ever so slightly forward and backward in time as it rides the hypersurface of the expanding universe. More precisely, from moment to moment it is just a little bit ahead of the average advancing surface and then just a little bit behind it.

Is a special mechanism for hyperinflation necessary?

As the hypersphere expands in the time dimension, it necessarily also increases in diameter in the spatial dimensions. Each layer of time is the thickness of one Planck unit, and like any regular object that is circular in cross section, it has a circumference of 2π times the radius. The early universe was thus not only much smaller, but also of much higher curvature than it is today. But because a Planck-sized unit of space is of finite (albeit minuscule) size, the curvature of a one-Planck unit of space (in the Planck epoch) is not infinite—although it would have been extremely high.

Although the proposed theory is consistent with a period of early hyperinflation, there is no need to postulate a *special* mechanism to drive a hyperinflationary interval near the beginning of time. If the size of the universe is considered to be the circumference of this hypersphere (as opposed to a surface area or a volume), the circumference of the universe doubled in the first Planck time of its existence (an increase of 100%, as it grows from a radius of 1 Planck length to 2, in the Planck epoch). With the addition of the next layer, it increased 50% more (from 2 lengths to 3). Subsequent layers increased it by 33%, 25%, 20%, and so on—a series that, by the time it reaches the present era, has a rate of increase that has for (more than) all practical intents and purposes been constant for a very long time—a very low number, not actually zero, but nearly so, and decreasing in size (as a percentage) at a rate of deceleration that is today not measurably different from zero. Today's rate of expansion would appear to be constant, both relatively (as a percentage) and absolutely (measured in Planck units). Indeed it has always been constant in absolute terms.

The model is thus consistent with a period of inflation—if by "inflation" we mean a period of time in which the rate of expansion, on a percentage basis, was much larger than it is today. But it does not require the postulation of a *special* inflationary mechanism.

Nothing can circumnavigate the expanding universe

Note that this hyperspherical model postulates a universe that is finite, unbounded, and growing, with a curvature that once was large, but has now effectively reached an asymptotic value of zero. Light traveling on the surface of this expanding hypersphere can continue in a straight line forever, but would never return to its starting point. If we were somehow to “freeze” the universe’s expansion, a wave of light would be able to circumnavigate the hypersphere in roughly the age of the universe times 2π. But the distance light would need to travel in an unfrozen, expanding universe would grow at a rate faster than light could travel along it.

The calculation is so simple that it barely needs to be performed. If the radius (age) of the universe at some moment is R (in Planck units of time), the circumference of a hypersphere of radius R is $2\pi R$ (in Planck units of distance). After an additional number of Planck layers have accumulated over a time increment r, the new circumference is $2\pi (R + r)$, an increase of $2\pi r$ Planck distances. But light traveling along the circumference would, during that time period, only be able to move r Planck units, which is a number quite a bit smaller than $2\pi r$.

There are large regions of the universe that never can, and never could, communicate with each other

The conclusion that light cannot complete a circumnavigation in such a universe is also clear when one considers the geometry of light cones in an expanding hyperspherical universe. This seems so obvious that I hesitate to include an illustration of it. Nevertheless, I have done so (Figure 1).

In a flat universe, any observer’s light cone (X) will eventually intersect anyone else’s light cone (Y), as in Figure 1A. But even if every local area in the universe has a very flat curvature, this does not necessarily imply that the universe as a whole is flat.

Consider the planar cross-section diagrammed in Figure 1B. If you are on the uppermost point of this expanding hypersphere, your light cone delimits two 45-degree angle regions off of the vertical (in the illustration’s arrangement) into your future (which in Figure 1B is termed “U”). Your opposite standing on the lowermost point has a light cone into the future that is 180° in the opposite direction (headed “D”). Those light cones never intersect. Likewise, an observer at “R” in Figure 1B would experience a future light cone expanding to the right, and one on the leftmost point “L” would have a future expanding to the left. All of these light cones are non-overlapping, a fact that is another proof of the impossibility of circumnavigating the universe’s circumference.

If we were to have the ability to go back to the universe when it was in its earliest, smallest stages, we would see that the currently observable section of our universe would have originated in a narrow region of a tiny, seething hypersphere. Some sort of near energy equilibrium would be reached within the boundaries of that region, without the necessity of having equilibrium established throughout the entire surface of the hypersphere. In the language of Figure 1B, the "U" region might be very different from the "D", "R", and "L" regions. Or it might not be very different. Neither of these facts are ones that future residents of those subregions would ever be able to communicate to each other, or to observe. In a universe as old as ours is now, the curvature everyone measures would be extremely close to zero—as far as our telescopes can see. We will never be able to *observe* the fact that the universe as a whole is still nearly spherical.

The universe cannot contract back to a singularity

It follows that the universe cannot contract back into a singularity. Matter exists in various parts of the universe that cannot communicate with each other. There is no way in which all of the universe's matter can come back together at one location. At most, one could imagine the end state of the universe as a number of black holes, each having accumulated all the mass in its own region of space (followed by their eventual evaporation). But those black holes cannot move fast enough to encounter the black holes that must be presumed to exist on the various poles of the universe.

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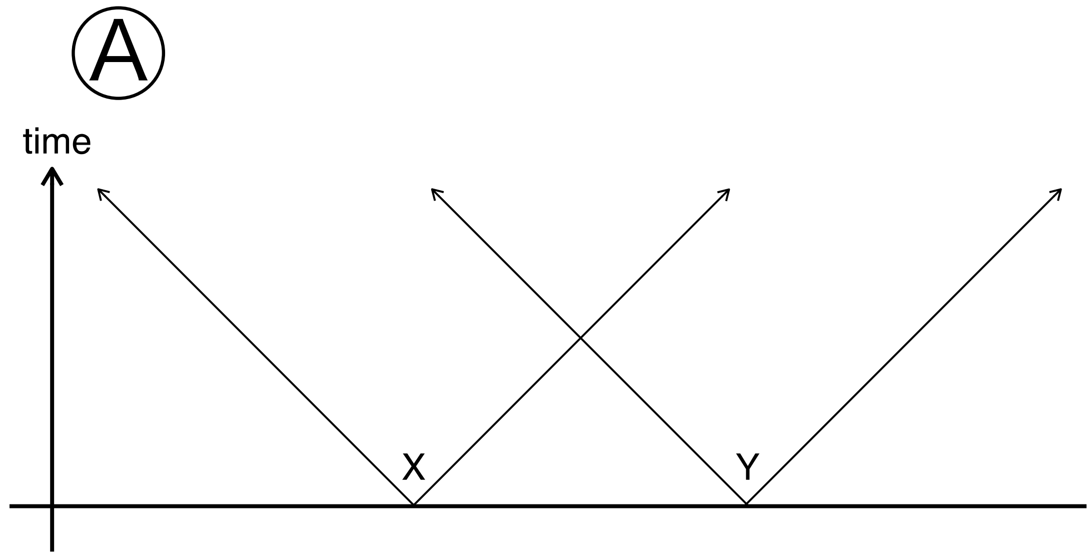
Figure Captions

Figure 1

A:
In a universe with a flat geometry, it is merely a matter of time before the light cones from two different points in space intersect. Thus, any part of the universe can eventually be observed from any specific point (X or Y) in the universe.

B:
In a universe that has positive curvature overall, light cones into the future from two different locations might never intersect (viz., the light cone for U will never intersect those for D, L, and R). Thus, there must exist parts of the universe that can never be observed from one's particular vantage point.

Note: For simplicity, this illustration fails to take account of how, in an expanding universe, light cones will form curves when graphed from the perspective of spacetime (Harrison, 2000, Figure 21.10). This does not alter the fundamental insight, however.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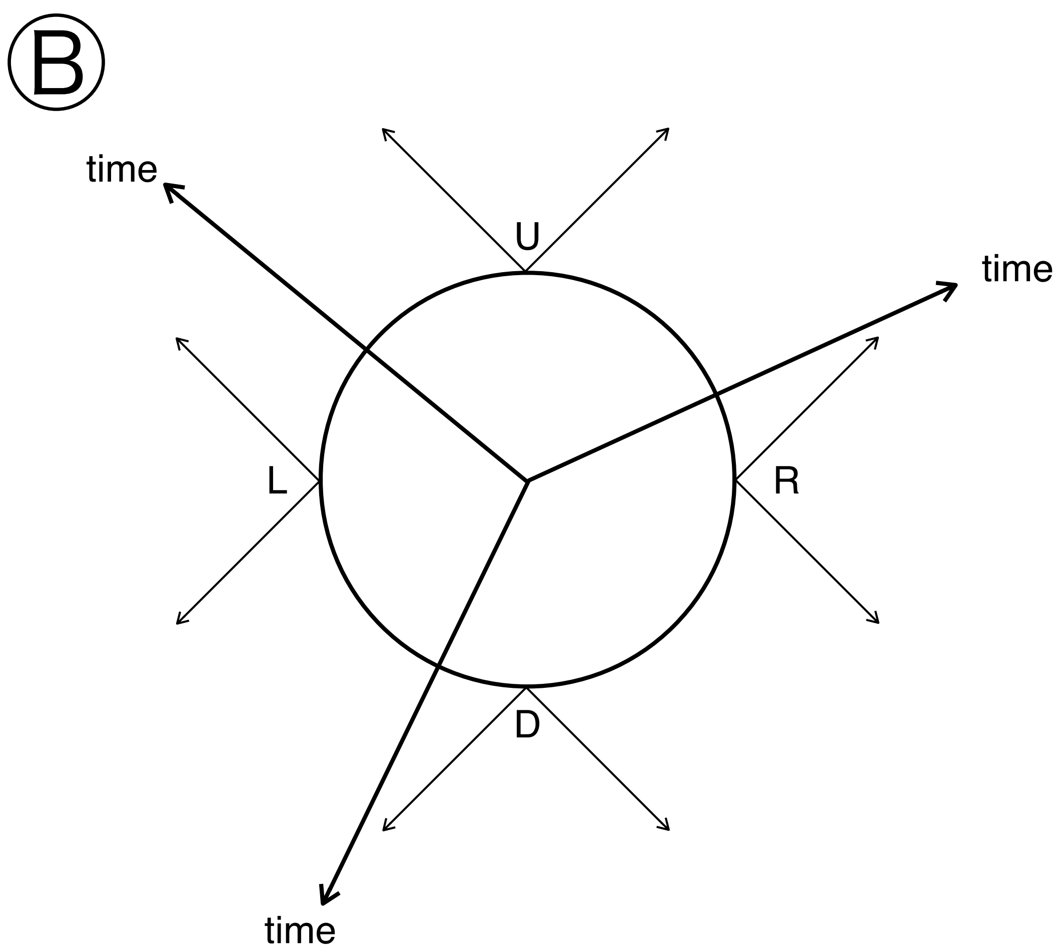
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