**Brane Theory, Presentism and the “Now” Problem**

Douglas S. Robertson

Cooperative Institute for Research in Environmental Sciences

University of Colorado

Boulder, CO 80309

e-mail: Douglas(dot)Robertson(at-sign)colorado(dot)edu

**Abstract:** Brane theory or M-theory requires seven additional dimensions beyond the four of standard space-time. I suggest that observational evidence for the existence of at least one of these additional dimensions can be found in the phenomenon that Rudolph Carnap called the “now” problem. I will argue that the main difficulty in explaining the “now” phenomenon is that it cannot be resolved within a conventional 4-dimensional spacetime, but it has a very natural and almost intuitive explanation in a higher dimensional continuum. A brane model for the universe not only provides a straightforward explanation for all of the observed properties of the “now” moment, including the asymmetry between the past and the future, it also eliminates the familiar paradoxes of time travel because the brane model does not allow time travel, which would entail a forbidden departure from the brane. The brane model provides a natural physical context for what philosophers call “presentism” because the brane exists only in (and indeed defines) the moving “now” or present moment at each spatial point.

**1. Introduction**

The “now” problem can be stated succinctly: Each of us constantly perceives a special moment in time that we call “now,” a point in time that appears to separate a determined past from an undetermined future. Whether the future is actually undetermined is a matter of some controversy, of course. Less controversially, the asymmetry between the past and the future is clearly seen in the fact that all of us have memories of the past but none of us have any memories of the future. Carnap stated that Einstein was bothered by the “now” problem and thought that it lay outside the realm of science (Carnap, 1963, pp. 37–38; see also Greene, 2004, chapter 5 and especially p. 141, and Smolin, 2013, pp. 91-92).

The main difficulty with the “now” phenomenon is that there is nothing in conventional physics, including Quantum Mechanics (QM) and General Relativity (GR), that would allow us to specify any particular “now” moment in time, nor does conventional physics allow such a “now” point to define the fulcrum of the asymmetries between the past and the future. As Einstein himself put it: "For us believing physicists, the distinction between past, present and future is only a stubbornly persistent illusion.” (quoted in Calaprice, 2000, p. 75). I suggest that the reason for this “stubborn persistence” is that the “now” moment is not an illusion, rather it is an observed fact that gives us important information about the nature of time and space.

This “now” moment is not a fixed point in time: It moves from the past toward the future (the so-called “arrow” of time[[1]](#footnote-1)). And it should be obvious that any motion of the “now” moment along the time direction is nonsense in any conventional physical theory based on standard 4-dimensional space-time (with a single time axis) because to express any motion, say the motion of an object along the *x*-axis of a coordinate frame, you require a time axis that is separate from the axis under consideration. For example, the motion of a moving object along an *x* axis is conventionally written as *x(t)*, to indicate that the *x*-position of the object is a function of time. For a simple example the position of a body that is moving with a uniform velocity *v* along an *x* axis might be written as:

*x(t) = x0 + v t*

Without a time axis (or *t* variable), *i.e*., if there is only an *x*-axis, we might have to try to express the *x* position as a function of *x, x(x),* which is nonsense, but it is related to the nonsense of trying to express the “motion” of a point in time, the “now” point, as a function of time: *t(t)* makes no more sense than *x(x).*

**2. The Brane Model**

This is where brane theory may be helpful. It appears at least to provide a context in which a solution to the “now” problem might be sought. To recap briefly: The original ten-dimensional string theory considered only one-dimensional strings that move in a ten-dimensional space, nine spatial dimensions and one time dimension. To explain why we perceive only four dimensions of space-time the additional six dimensions were postulated to be curled up or “compactified” into structures called Calabi-Yau spaces that are roughly the size of the Planck length (~1.6 x 10-35 meters) and are thus too small to be perceived in any experiment using present-day technology. (see, e.g., Susskind, 2008, pp.. 339-336)

The newer eleven-dimensional M-theory or brane theory extends the idea of one-dimensional strings to N-dimensional “branes,” where strings are one-branes, but there are also two-dimensional branes (“membranes,” the origin of the word “brane”), and three, four, five . . . dimensional branes, up to a maximum of nine dimensions. Thus in brane theory the additional seven dimensions are not necessarily compactified (Susskind, 2006, pp. 276-284). And these additional dimensions are not necessarily spatial dimensions—some of them might be time-like. The possibility of additional extended time dimensions has been discussed recently (see, *e.g*., <http://physics.usc.edu/~bars/>) but I believe that the relation of additional time dimensions to the “now” problem is as yet unexplored.

In M-theory the universe that we observe might be modeled as a 3-brane that is moving along a time axis. As Greene put it: “Could it be that the four-dimensional spacetime developed by Minkowski and Einstein is actually the wake of a three-brane as it evolves through time?” (Greene, 2004, p. 388). “String theorists call this the *braneworld scenario*.” (Greene, 2011, p. 114) Greene does not explore the implication of his question for the “now” problem but in this model the local “now” point in time would be simply the time value at the intersection of the local or nearby part of the 3-brane with the time axis, and this local “now” point would move in the time direction as the brane “evolves through time.”

But as we noted above, the word “move” in the preceding sentence is problematic if there is only a single time axis. The motion of a point along the time axis is meaningless if we try to express it as *t(t)*, just as the motion of an object along the *x*-axis of a coordinate frame cannot be expressed as *x(x),* it must be expressed as *x(t).* But the problem can be resolved if there is a second time axis that we might call *t\*.* There is now no difficulty in expressing the kinematics of the temporal motion of a moment called “now” if its position along the conventional time axis, *t*, is moving as *t(t\*).* This requirement for a second or *t\** time axis is quite general: It holds for both a universal constant rate of time flow as in Newtonian physics as well as for a local rate that depends on velocity and gravitational potential, as in GR. Lubashevsky, for example, (2016) has discussed two-dimensional time in the context of ordinary Newtonian physics.

And the observed asymmetries between the past and the future may have a natural explanation in terms of this model of the universe as 3-brane that is moving along a time axis with motion that is a function of the second time axis, *t\**. The past is simply the set of points in time that the local part of the 3-brane has already visited, and the future is the set that the 3-brane has not yet visited, with “already” and “not yet” specified in terms of *t\** and not *t*.

**3. Further Properties of the “Now” Moment**

It is important to understand that the “now” moment defined by the time value of a point on a 3-brane is defined only locally on the 3-brane. It is not a Newtonian-style universal “now” moment that would be the same everywhere. “Now” will generally be different at each point on the 3-brane with differences that are specified by the differential equations (presumably M-theory equations) that define the brane. The fact that there are small differences between the “now” moments of nearby observers poses no conflict with observation so long as the observers are close enough in time (and space) to be able to exchange information using photons and phonons exactly as they are observed to do.

In fact, one of the important properties of the “now” phenomenon is that everyone perceives essentially the same “now” moment locally to the accuracy that perception allows. In classical Newtonian theory this presents no difficulty because everyone in the universe always experiences exactly the same “now” moment. But in GR all observers should be experiencing their own “now” moments that “move” at rates that depend on their relative velocities and gravitational potentials. And because those “now” moments are moving at different speeds (measured against *t\**) we should expect observers to become separated in time, with everyone experiencing a different “now” moment as expressed by the readings on their respective wristwatches. Similarly, if two observers are moving along a spatial axis with different speeds, we should expect them to become separated in space.

The time differences between the separated “now” moments for different observers could be arbitrarily large. For example, suppose you have a spaceship that can reach nearly the speed of light. The spaceship crew travels to a star that is ten light years away and then returns. Further suppose that elapsed time on the ship is, say, one week, while on Earth the elapsed time until the return of the spaceship is about twenty years. When the crew returns, why is it that that their “now” moment is still synchronized with the one back on Earth? Since they have experienced only a week of elapsed time, why isn’t their “now” moment twenty years or so in the past of the Earth-bound observers? But if it were, then by waiting twenty-odd years here on Earth they should be able to observe their own return as seen from the Earth-fixed frame. Clearly that would not happen because, among other things, it would involve a violation of conservation of energy, a duplication of the mass-energy of the spacecraft (see the discussion below). But what does happen? It seems somewhat odd that everyone’s “now” moment would remain locally synchronized even though their respective wristwatch readings do not agree.

GR makes no reference to a “now” moment and therefore has nothing to say about the matter, as Einstein was aware. But brane theory may be able to resolve this problem because branes are “sticky.” They hold on to things. As Greene says: “Branes are the only locations where the endpoints of string snippets can reside . . . String snippets can freely move within and through a brane, effortlessly gliding from here to there, but they can’t leave it . . . In a braneworld, the strings that make up you and the rest of ordinary matter, are snippets. While you can jump up and down, throw a baseball . . . all with absolutely no resistance from the brane, *you can’t depart the brane*.” (Greene, 2011, p. 116; Greene’s italics).

Therefore in the model of the universe as a 3-brane that is moving in the time direction (moving with respect to *t\**) all observers will be confined to that brane, and confinement to the brane should be sufficient to synchronize the “now” moments of nearby observers in the brane, as observed, regardless of the readings on their individual wristwatches: All nearby observers on the brane will be close to the same “now” value because any discontinuity or step function in the local “now” values would constitute a discontinuity in the brane. But we know that branes cannot have discontinuities because they are solutions to the differential equations of M-theory, and continuity is the one property that is possessed by all of the solutions to every differential equation, as Poincare noted when he developed topology. Therefore the observation of local synchronization of the “now” moment may provide observational evidence not only for the existence of an additional time dimension but also for the existence and properties (continuity) of branes themselves.

If “now” moments were not synchronized somehow then conservation of energy would fail. Conservation of energy is deeply linked to the “now” concept, as many discussions of time travel fail to consider. If a time machine were transported a year into the past then its mass-energy would be lost in the “now” moment, and it would appear suddenly one year in the past. Also the spacecraft behavior in the example described above would produce a similar violation of conservation of energy if its “now” moment were not synchronized among local observers. But if everything in our universe is confined to a 3-brane then problems of conservation of energy would appear to be tractable—no mass or energy can move off the brane.

It therefore appears that the simplest way to make sense of both the “now” moment in time and conservation of energy would be to assume that we are confined to a 3-brane that is moving in the time direction in a higher dimensional space.

**4. Philosophical Implications**

The model of the universe as a moving 3-brane resolves the old philosophical difficulty of the observed asymmetry between space and time, that we are free to move in three spatial directions (with some constraints), but, although we do move in the time direction, we are not free to choose our motion in that direction. In particular, we cannot move away from the local “now” moment in time. Such an asymmetry is a natural consequence of living in a 3-brane that is moving in time. We are free to move in three spatial directions without leaving the 3-brane, but the brane has no extent in the time direction so any attempt to move away from the “now” point in the time direction would involve leaving the brane, which is not permitted. We are therefore forced to simply move along with the brane as it moves in that direction. Notice that in this brane-world model “time travel” is impossible because we cannot move away from the “now” moment, and all of the familiar paradoxes of time travel do not arise.

The moving 3-brane model provides a natural context for the school of philosophy called “presentism,” whose fundamental idea is that the past and future do not exist, only the present or “now” point in time actually exists. In the 3-brane model the brane that defines the “present” (the set of “now” values across the brane) is all that actually exists, at least so far as can be observed from within the brane, as the presentists postulate. Romero and Perez (2014) note that: “The compatibility of presentism with the theories of special and general relativity was much debated in recent years.” But, as we noted, GR has nothing to say about the “now” moment. In other words, in debating the compatibility of presentism with GR, philosophers were in effect trying to understand the properties and behavior of the “now” moment by using a theory (GR) that provides no information about the “now” moment. Therefore any discovered or purported inconsistency between GR and presentism may well represent a deficiency in GR rather than in presentism, a deficiency related to the inadequacy of 4-dimensional models to encompass or explain the behavior of the “now” moment in time. The model of the universe as a 3-brane moving in a higher dimensional continuum requires the full formalism of brane or M-theory, and therefore any discrepancies with GR should be resolved in that formalism and are not necessarily permanent objections to presentism.

A minor technical issue might be resolved by the existence of a second time axis. In the original formulation of 10-dimensional string theory the six additional dimensions beyond the standard 3 space and one time dimension were thought to be compactified into a 6-dimensional Calabi-Yau space. With M-theory’s 11 dimensions there are 7 dimensions that would have to be compactified. But we do not know of any 7-dimensional Calabi-Yau spaces. We know how to construct them only in spaces of complex dimensionality which translates into an even number of real spatial dimensions. Whether the absence of odd-dimensioned Calabi-Yau spaces is a real property of these spaces or simply reflects a deficiency in our current analytic techniques is not presently known (See Yau and Nadis, 2012, p. 150). But if there are two extended time dimensions then there are only six remaining dimensions (out of 11) that might need to be compactified into a six-dimensional Calabi-Yau space.

But of course the model of the universe as a 3-brane that moves in time provides a different answer to the question of why we perceive only three spatial dimensions in an eleven-dimensional universe, an answer that does not require compactification of the additional dimensions. Observers who are confined to a 3-brane would not be able to observe any additional dimensions that might exist, regardless of whether those dimensions are compactified or not.

Einstein’s difficulty with the “now” problem may center on the fact that classical 4-dimensional spacetime is inadequate to resolve the problem. Einstein was aware of the possibility of additional spatial dimensions beyond the 4 of space-time at least since Kaluza’s introduction of a fourth spatial dimension. But I am not aware that he ever considered the possibility of additional timelike dimensions, or the possibility that such timelike dimensions might be needed to specify the motion of a “now” moment along the conventional time axis, and the idea of the continuity of a 3-brane moving in a higher dimensional continuum was a half-century or so ahead of his time.

Discussions of the “now” phenomenon in the literature often fail to appreciate the need for an additional time dimension to deal with the motion of the “now” moment in the time direction. Additional dimensions were seldom considered prior to the development of string/brane theories in the late twentieth century, with the notable exception of 5-dimensional Kaluza-Klein theories. And even today the eleven dimensions of brane theory are not uniformly accepted by theorists considering the “now” phenomenon. For example, in his recent book about “now,” Muller calls eleven dimensions “crazy.” [2016, p. 149]. Of course it is possible that the idea of eleven dimensions is wrong but it is certainly not crazy. Any such prejudice against the idea of additional dimensions will probably preclude an understanding of the “now” phenomenon, since, as noted above, the “now” point cannot move along a time axis unless there is an additional time dimension.

**5. Summary and Conclusions**

This brane-theory model is consistent with the following five observed facts about the “now” phenomenon:

1. There is a “now” moment that is observed constantly by every waking person.
2. This “now” moment moves “forward” in the time direction, as measured by a wristwatch.
3. The “now” moment is the point in time that appears to separate a determined past from an undetermined future. The asymmetry between the past and the future is perhaps best seen in the fact that all of us have memories of the past, and none of us have memories of the future.
4. Observers who are close together in 3-space will also be close in their “now” values on the time axis, despite possibly sizeable differences in the readings on their respective wristwatches.
5. Observers are free to move in three spatial dimensions but are not able to move away from the moving “now” moment in the time direction.

These facts can be confirmed by personal observation and none of them is explained or modeled correctly by either conventional GR or QM. But all of them can be neatly explained by the model of a 3-brane moving in the time direction. Indeed it is somewhat astonishing that although neither GR nor QM separately have any information about the “now” phenomenon, the theory that successfully combines them, brane theory, does contain a natural explanation not only for the existence of the “now” phenomenon, but also for all of its observed properties.

To better understand this explanation it might be useful to try to visualize the brane model. However, most of us have some difficulty picturing a rippling three-brane that is moving in time. So for visualization purposes it might be convenient to drop down to two spatial dimensions and picture a two-brane instead of a three-brane: Imagine that we have two spatial axes, *x* and *y*, in a horizontal plane, and a time axis, *t*, in the vertical direction. Next imagine that this model is filled part-way up with water, so that the rippling surface of the water (the surface, not the water itself) represents a two-brane that moves in the vertical or time direction. We can call the time value of the surface of the water at any point *tw*. Ripples on the water will cause *tw* to vary with a velocity of *dtw/dt\**, a velocity that changes sign as the ripples rise and fall. But time rates are never negative, so imagine further that there is a firehose pouring water in below the surface so that the average surface value *tavg* moves vertically with a velocity *dtavg/dt\**. If *dtavg/dt\** is larger than the largest negative ripple velocity then all of the “now” values, *tnow* = *tw* + *tavg* across the 2-brane will move with a varying velocity *dtnow/dt\** = *dtw/dt\** + *dtavg/dt\** that is always positive upward. The value of *tnow* now agrees with the basic properties of our observed local “now” values that move with variable speed but always upward or forward in time. Recall that this 2-D surface or two-brane holds all of the matter and energy (and observers) in the universe. Nothing can move off the brane.

This simplified model with only two spatial dimensions preserves many of the critical features of the full 3-brane model including continuity of the brane and the concomitant requirement that observers on the brane who are nearby in space (x-y values) must also be close to the same “now” or *tnow* value. In addition it illustrates the need for a second or *t\** time axis to express the motion of the local “now” values, *dtnow/dt\**, in the time (*t*) direction. And the model shows why at any point on the brane observers are free to move in two spatial directions without leaving the brane, but cannot move away from the “now” point *tnow* in the time direction without leaving the brane. And perhaps most important, this simplified model makes clear why the “now” phenomenon exists at all: Because the 2-brane is two-dimensional with both dimensions spatial, it can have no thickness or extent in the time direction. It therefore occupies only a single point in time at any spatial location, a point that specifies the moving local “now” moment.[[2]](#footnote-2) If the brane had any significant thickness in the time direction it would not define a unique “now” moment at that spatial location. In effect the presence of a moving 2-brane breaks the symmetry between the three (x, y, t) dimensions of this model. Time may have been exactly the same as space until a spatial 2-brane that ripples and slides in the time direction was introduced that confined all observers to its two spatial dimensions. The 2-brane therefore breaks the symmetry between the spatial and the time dimensions.

We can convert this simple 2-brane model to the full 3-brane model by first restoring the missing third spatial dimension of the brane (while maintaining zero thickness in the time direction) and then replacing the hydrodynamic equations of water ripples with the differential equations of brane theory that define a 3-brane. We will then have a 3-brane model whose spatial points each occupy a single point (“now”) in the time direction, a point that moves with a local velocity (*dtnow/dt\**) specified according to the brane equations. This 3-brane model is first of all a model that is consistent with both QM and GR. That consistency with QM and GR was a difficult combination to accomplish but it is exactly what the brane equations of M-theory were designed and constructed to do. And the model has a natural explanation not only for the existence of an observed “now” moment at every spatial point but also for the observed asymmetry between the past and the future: The past is the set of time points that the local part of the brane has already visited, and the future is the set that it has not yet visited, with “already” and “not yet” expressed in terms of *t\**. It also explains the fact that observers who are close in 3-space will observe “now” moments that are close in time. And it provides a natural explanation for the fact that observers are free to move in the three dimensions of the brane, but are unable to move in the time direction away from the local “now” moment. None of this is handled in conventional QM or GR. The model therefore fills a gap in conventional physical theories while remaining completely consistent with those theories: The idea of 3-brane that is moving in the time direction is the main thing that was missing from those theories separately. And finally, the observed motion of the “now” moment along the time axis *t* provides observational evidence for at least one (*t\**) of the seven additional dimensions required by M-theory.

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1. One of the difficulties found in many discussions of time in the literature centers on a failure to distinguish between the time axis and the “now” point on the time axis. Thus you often find writers discussing the “flow” of time and the “arrow” of time when they are really talking about the motion of the “now” moment along the time axis. This sloppy terminological use of the word “time” can lead to serious and unnecessary confusion, much of which probably results from the fact that the “now” point is the only point on the time axis that we ever actually observe directly, but that is not a good excuse for careless or imprecise use of the word “time.” [↑](#footnote-ref-1)
2. If we are making measurements at the Planck scale then this discussion might need to be modified slightly: The thickness of the brane in the time direction is probably not less than the Planck time (approximately 5.39 × 10 −44 s), because in brane theory generally it makes no sense to talk of time durations smaller than this. However, for the discussion here, the Planck time is an adequate approximation to a zero time interval. [↑](#footnote-ref-2)