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Unwinding the universe: a brief look at String Theory

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"String Theory" has been a buzz-word in contemporary physics for years. It is at the very edge of theoretical ontology, predicting bizarre qualities of the universe – even claiming we exist in 11-dimensional space-time. These predictions may be strange, but the Theory can account for many of the laws of the universe if we put aside our preconceptions and accept the strange possibilities the Theory suggests.

The basic precepts of String Theory explain that the most elementary particles of the universe are tiny one-dimensional threads often thought to close in upon themselves, forming loops. These strings combine in various ways to form all the other particles that we know about in the universe, such as electrons, photons, quarks, etc. Because these threads are one-dimensional, they can vibrate at different frequencies and wavelengths, each pair of which corresponds to a different energy state. These different energy states, in turn, produce different properties to varying degrees, including mass, electrical charge, etc.

The foundation for the assumption that these strings exist is a simple one. For years physicists have known that Einstein's Theory of Relativity can successfully describe how the macroscopic universe behaves, and that quantum mechanics does the same for the microscopic world. However, when these two theories combine, the results are very problematic. As we try to understand what the universe looks like at the Planck length[1], about 1.6×10^{-35} metres, relativity and quantum theory paint contradictory pictures. The former requires space-time to be flat and smooth (assuming there are no massive bodies in proximity). The latter describes a chaotic place where energy and mass are spontaneously and continuously created and annihilated. Taking strings into account, the Theory essentially tells us that the universe doesn't really ever 'get' as small as the Planck length, as even the smallest particles – strings – are larger than this size.

The Theory has a number of other positive consequences. First, if we assume that the particles we have already observed are composed of these strings, then different possible string vibrations and wavelengths let us account for the different properties these particles exhibit. For example, the Theory may explain why it is that an electron and a proton have the same magnitude of charge while one is almost 2000 times the mass of the other.

Even more impressively, perhaps, the Theory predicts the existence of certain particles that theoretically should exist, but which we have not yet been able to observe. There are four forces in the universe: the electromagnetic force, the gravitational force, the strong force, and the weak force. (Most of us know of the first two. The strong and weak forces account for atomic nuclear cohesion and decay, respectively.) Each force has a corresponding 'messenger' particle that works to 'tell' other particles how to act. For instance, photons play this role in the electromagnetic force, causing charged particles to be attracted or repelled from one another. We have been able to observe the messenger particles of the strong and weak forces as well, but the messenger particle of the gravitational force – the graviton – is as of yet unseen and not proven to exist. One of the first strengths noticed in String Theory was that it not only tells us that all four forces must exist, but goes on to tell us what the graviton must 'look like' as well!

Even with these strong theoretical consequences, there is reason to be wary. There are many different properties the strings must account for, and each one must be represented by a different 'way' in which the string can vibrate. The three spatial dimensions and one time dimension that we experience simply do not allow for enough freedom – we need more than up/down, left/right, forward/backward, and before/after. For this reason, the Theory tells us that the universe must have many more dimensions – current theories estimate 11, including that of time.

As one of the oddest predictions of String Theory, for many this is enough to disprove the whole idea. If the universe contains so many dimensions, why have we only ever observed four? Even if we accept that our observation and the truth can be very distant from each other, where is there any room for more spatial dimensions anyway?

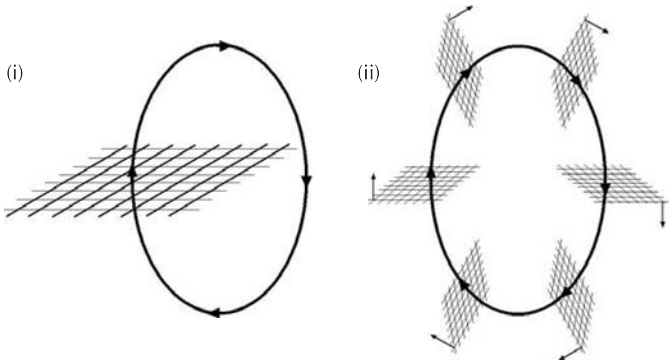
It is pretty much impossible for us to visualize one extra dimension, let alone seven, but even if we can't truly picture it we can try to describe it through analogy in three dimensions. Consider, first, two of the dimensions as a flat plane. If the third dimension is to be "closed", as the extra dimensions described in String Theory are often held to be, not only is it at right angles to the plane, but it also forms a loop. It is important to note that this third dimension appears at every point in the plane. The loop we draw is simply an example of how the dimension appears from a single point on the original plane. Also, when we consider the plane, we are only looking to a small cross-section of the dimensions it represents. These dimensions, too, may be closed and form their own loops. Now at every point the three dimensions are orthogonal, so you have to imagine that as you travel around the loop, the plane of the first two dimensions travels with you. If this seems confusing, then you've probably gotten it right!

To extend this picture to multiple dimensions, we repeat the procedure. Let's begin with a fourth spatial dimension. Imagine a plane that somehow contains three dimensions. (This is a contradiction of terms, but if we could picture it any better, then extra dimensions wouldn't be a problem to begin with!) We imagine a loop, just as in the three-dimensional case, only this time the first three dimensions all travel along the loop as you follow its path, always orthogonal to the fourth. Repeating this six more times, each times with a plane that represents more dimensions, explains how the 10 spatial dimensions relate to one another.

This isn't the entire picture, as this doesn't explain why we don't notice the extra dimensions. This has to do with thethe sizes of the extra dimensions. It may seem bizarre for a dimension to have a size at all, but this comes naturally when the dimension forms a loop; all finite loops have a finite radius and circumference. If the three 'everyday' spatial dimensions are closed, they are also very large – their size is that of the universe (which, too, would be closed). However, the extra dimensions proposed in String Theory are essentially too small for us to notice.

Consider, as an analogy, a very fine fishing line hanging taut in the air in front of you. If the wire is thin enough, and close enough to your face, then you can never resolve its image in your eyes, and may even completely disappear from your vision, as if it were invisible. The sizes of the extra dimensions' loops are much smaller than that of the fishing line. Unlike the line though, dimensions aren't solid, and so we carry on in three dimensions without even realizing there may be many more that we pass right through everyday.

Another way to consider the same idea is to imagine traveling around the dimensional loops at a certain speed. Clearly, the amount of time it takes to do so depends on how big the loop is. Now if we make the loop small enough, eventually such a trip would take no time at all. We can even imagine it to be so small that any movement made on the loop involves a number of trips made around it, without the traveler even noticing.



Picturing further dimensions: (i) Adding a closed, third dimension to a plane, we draw a loop. Recognize the same loop occurs at every point on the plan – we only visualize it once. (ii) As we proceed along the loop, the plane rotates with us, remaining always orthogonal to the loop

It should be noted that these analogies offer only a way to think about the consequences of the Theory. No one can properly imagine more than three spatial dimensions – it is simply impossible – and so these results are incredibly difficult to envision, much less accept.

Even if we accept its odd theoretical requirements, String Theory is nowhere near completion. It seems there is a different version of the Theory for every string theorist out there – and not a single prediction has been verified in any way. Because of such difficulties, and the fact that they remain unresolved after 30 years of research, there are more and more physicists who oppose the current expenditure of resources and energy on String Theory research. They feel that perhaps it is a futile exercise, given that we have made no unanimous advances or proven predictions, and that the Theory truly comes out of a desire to explain the universe elegantly and not out of any real experimental data.

Unfortunately, this is an issue that will remain unresolved until a final version of the Theory is developed or until a prediction is proven successful. One thing is certain – the more we find out about the most basic particles that make up the universe, the more we find that they are nothing like what we ever imagined.

Further reading for those interested, who don't necessarily have a physics background:

1. Brian Greene's *The Elegant Universe and The Fabric of the Cosmos* explain String Theory to the layperson from the string theorist's point of view.
2. Lee Smolin explains why he abandoned work in String Theory after years in the field in *The Trouble with Physics: The Rise of String Theory, the Fall of a Science, and What Comes Next*

[1]This is a particular constant that arises naturally from other universal constants, such as the speed of light.